This is a reproduction of a library book that was digitized by Google as part of an ongoing effort to preserve the information in books and make it universally accessible.

Google™ books

https://books.google.com

THE LIBRARY
OF THE
UNIVERSITY OF MINNESOTA

CLASS En 620.5
BOOK W71

INDEX.

Vol. V. Experimental Wireless & The Wireless Engineer 1928.

I. GENERAL INDEX.

PAGE

Abacs. The Application of Alignment Charts to Valve Characteristics. M. Reed 571
Abstracts and References (*see separate index for details*), 31, 97, 162, 221, 285, 341, 397, 460, 516, 578, 637, 683
Accuracy and Calibration, Permanence of Variable Air Condensers for Precision Wavemeters, W. H. F. Griffiths .. 17, 63
A.C. for Heating Valve Filaments, The Use of, C. W. Oatley 380
A.C. Mains Unit (Patents) 596
A.C. Valve Filaments (Patents) 111
Aerial, Equivalent Inductance and Capacity (Editorials) 297, 357
(Correspondence) 384, 513
Aerial Reflector Systems (Plane) Polar Diagrams, T. Walmsley 575
(Correspondence) 636
Aerial Systems, Short-wave, E. Green .. 304
(Correspondence) 513
Aerial Systems (Patents) 172
Aerials, Generalised Theory, R. M. Wilmotte .. 119
Aerials, Half-wave, Radiation Resistance and Energy Capacity, E. Green 82
(Correspondence) 284
Aircraft D.F. Installation (Patents) 107
Alignment Charts, Application to Valve Characteristics, M. Reed 571
Allocation of European Broadcast Wavelengths, Siffer Lemoine 386
Amalgamation of "Amateur Photographer" and "New Photographer" 473
Ammeters, Non-contact Thermo-junction, Design of, F. M. Colebrook and R. M. Wilmotte 538
Amplification, H.F. Push-Pull (Patents) .. 415
Amplification, Resistance, New Method, with Screened-grid Valves, J. J. Dowling .. 61
(Correspondence) 284, 513
Amplification of Small Currents (Correspondence) 42
Amplification, What is Straight-line? (Editorial) 600
Amplifier H.F., Stability of the Tuned-grid Tuned-Plate, R. T. Beatty 3
(Errata) 112, 147
Amplifier, New Balanced (Patents) 474
Amplifiers and Transformers, Microphone, H. L. Kirke 361, 443
Amplifiers, H.F., Good Quality in, C. C. Inglis 132
(Correspondence) 220, 282
Amplifiers, H.F. (Patents) 355
Amplifiers, L.F. (Patents) 536
Amplifiers, Photo-Electric (Patents) 597

PAGE

Amplifiers, Resistance, Calculations for, A. L. M. Sowerby 201
Amplifiers, Resistance, Graphical Construction for, W. A. Barclay 499
Amplifiers Retro-action in, H. A. Thomas .. 245
(Correspondence) 385
Amplifiers, Screened-grid (Patents) 413
Amplifiers, Stabilising (Patents) 352
Amplifiers, The Final or Power Stage, M. von Ardenne 556
Antennæ, Generalised Theory of, R. M. Wilmotte 119
Apparent Demodulation of a Weak Station by a Stronger One, R. T. Beatty 300
Application of Condensers to the Measurement of Larger Radio-frequency Currents, P. R. Coursey 565
Atmospherics, Present State of Knowledge of (*Abstract of B.A. Paper*), R. A. Watson Watt 629
Attenuation of Wireless Waves Over Land (*I.E.E. Paper*), R. H. Barfield 25
Automatic Volume Control (Patents) 414
Automatic Direction-finding (Patents) .. 415

Balancing Inter-Electrode Capacity (Patents) 535
Balancing Condensers (Patents) 598
Banks of Paralleled Valves Feeding Resistive Loads, W. Baggally 315
BOOK REVIEWS:
  Wireless Direction-Finding and Directional Reception, R. Keen 84
  The Propagation of Radio Waves along the Surface of the Earth and in the Atmosphere, P. O. Pedersen 150
  The Interaction of Pure Scientific Research and Electrical Engineering Practice, Prof. J. A. Fleming 150
  A Study of Radio Direction-Finding, R. L. Smith-Rose 151
  The Thermionic Valve, F. Goddard 151
  Les Filtres Electriques, L'Alimentation des Postes Recepteurs, M. Veaux 151
  Thermionic Vacuum Tube Circuits, L. J. Peters 203
  Practical Radio Construction and Repairing, Moyer and Wostrel 203
  American Geophysical Union, *Abstr.* (Terrestrial Magnetism and Electricity) 204
  Elements of Radio Communication, E. W. Stone 204
  Electric Rectifiers and Valves, A. Güntherschulze and N. A. de Bruyne 204

PAGE

Book Reviews (Continued):
  The Four-Electrode Valve, F. Goddard .. 204
  Lefax Radio Handbook 220
  Amateur Radio Vocabulary in Five Languages, " Radiokonstrukce " 266
  Der Sprechende Film, D. von Mihály .. 266
  Pitman's Technical Dictionary of Engineering and Industrial Science 338
  Wireless Principles and Practice, L. S. Palmer 338
  The Instrument World 339
  Intermediate Electricity and Magnetism, R. A. Houston 339
  New Theory of Generation and Propagation of Wireless Waves in Space, H. R. Khan 377
  Investigation of a Rotating Radio Beacon, R. L. Smith-Rose and S. R. Chapman .. 514
  Patent Law and Practice, A. W. Griffiths 615
  Experimental Radio, R. R. Ramsay .. 615
  Handbuch der Experimental Physik, Wienharms 682
Bridge for the Measurement of Inductance and Capacity, Dr. G. Zickner 280
British Association Paper, Present State of Knowledge of Atmospherics, R. A. Watson Watt 629
Broadcasting, Single-wave (Patents) 536
Broadcasting Stations, The Design and Distribution of (*I.E.E. Paper*), P. P. Eckersley 189

Calculations for Resistance Amplifiers, A. L. M. Sowerby 201
Calibrating a L.F. Valve Generator, T. S. Rangachari 633
Capacity, Inter-Electrode, Balancing (Patents) 535
Capacity, Inter-Electrode, The Harmful Effects of, M. von Ardenne and W. Stoff 509
Capacities, Small Variable, Measurement of, W. H. F. Griffiths 452
Catalogues Received 174
Characteristic Curves of the Four-Electrode Valve, N. R. Hall 198
Choke Coils and Transformers, Design (Editorial) 49
  (Correspondence) 220, 340
Choke Modulators (Patents) 109
Circuits, Stabilising (Patents) 172
Coil-Windings (Patents) 296
Coils, Single Layer, Dielectric Losses in, W. Jackson 255
Combined Land-line and Radio Systems (Patents) 414
Condenser, New Precision Wavemeter, W. H. F. Griffiths 278
Condenser, Tuning (Patents) 233
Condensers, Variable Air, Accuracy and Calibration Permanence, for Precision Wavemeters, W. H. F. Griffiths .. 17, 63
Condenser, Variable, Correct Characteristic for, Lieut.-Col. K. E. Edgeworth .. 148
Constant-Capacity Coupling (Patents) .. 352
Constant-Coupling Circuit (Patents) .. 109, 535
Copper-Oxide Rectifier (Editorial) 1
Correspondence, 42, 220, 282, 340, 384, 593, 635, 680
Couplings, High Resistance (Patents) 536

PAGE

Damping due to Grid Current, M. Reed .. 322
  D. C. Smoothing Devices (Patents) .. 110
Definitions, Some Fundamental (Editorial) .. 599
Definitions, Some Fundamental, R. M. Wilmotte 607
Demonstration of a New Precision Wavemeter Condenser, W. H. F. Griffith .. 278
Design and Distribution of Wireless Broadcasting Stations for a National Service (*I.E.E. Paper*), P. P. Eckersley 189
Design of Choke Coils and Transformers which carry a Direct Current (Editorial) .. 49
  (Correspondence) 220, 340
Design of Non-Contact Thermo-junction Ammeters, F. M. Colebrook and R. M. Wilmotte 538
Detector Valve, New Idea for 515
Detectors and Amplifiers, Effect of Anode-grid Capacity, W. B. Medlam 545
Diaphragms, Loud Speaker (Patents) 475, 699
Dielectric Losses in Single Layer Coils at Radio Frequencies, W. Jackson 255
Dimensionality in Wireless Equations, W. A. Barclay 211
Direct Reading Valve Tester, M. G. Scroggie 480
Directional Wireless (Patents) 535
Direction Finding (Patents) 234
Direction Finding, Automatic (Patents) .. 415
Distortion, Preventing L.F. (Patents) 48
Ditton Park Research Station, Fire Damage (Illustration) 30
Double Superheterodyne, A 669

Editorials:
  The Copper-Oxide Rectifier 1
  The Design of Choke Coils and Transformers (D.C.) 49
  Potential Difference and Capacity in A.C. Problems 113
  Some Further Problems in Potential Difference 175
  Symbolical Algebra 237
  Self-Induction of Single-turn Circuits of Various Shapes 238
  The Equivalent Inductance and Capacity of an Aerial 297
  The Equivalent Inductance and Capacity of an Aerial with Inserted Tuning Coil or Condenser 357
  Quality *versus* Selectivity in Distant Broadcasting Reception 417
  A Chapter in the History of Radio Measurements 477
  Olympia Radio Show, 1928 537
  Some Fundamental Definitions 599
  What is Straight-line Amplification ? .. 600
  Radio Transmission and the Upper Atmosphere 657
Effect of Anode-grid Capacity in Detectors and L.F. Amplifiers, W. B. Medlam .. 545
Eliminators, H.T. Voltage Regulation in (Patents) 532
Eliminator Smoothing Circuits, Surges in, A. G. Warren 601
Equivalent Inductance and Capacity of an Aerial (Editorial) 297

E11620.5
W71

PAGE

Equivalent Inductance and Capacity of an Aerial with Inserted Tuning Coil or Condenser (Editorial) 357
  (Correspondence) 384, 513
ERRATA 112, 636
ESPERANTO SECTION, 40, 105, 169, 231, 291, 350, 411, 472, 529, 592, 650, 695
EXHIBITION :
  The Physical Society's 94
  Olympia, 1928 (Editorial) 537

Fading Effects, Minimising (Patents) .. 531
  Fading Measurements in India on the Short-wave Station PCJJ, T. S. Rangachari 501
  (Correspondence) 635
Fading, Prevention of (Patents) ..45, 474, 700
Fading, The Study of (*I.E.E. Paper*), Prof. E. V. Appleton 267
Ferranti Precision Meters 131
Final or Power Stage of Amplifiers, M. von Ardenne 556
Flexible Tuner (Patents) 112
Formulæ for the Self-Inductance of Single-turn Circuits, Establishment of, R. G. Allen 259
Four-Electrode Valves (Patents) 296
Frenotron Valve, A Vienna Novelty 214
Frequency-Doubling (Patents) 532
Frequency Modulation (Patents) 655
Frequency-Stabilising Devices (Patents) .. 534
Fultograph Picture Receiving Equipment (Illustration) 628

Gas-filled Rectifiers (Patents) .. 173, 598
  German H.T. Mains Unit 251
Gramophone Pick-ups (Patents) 597
Graphical Computation, M. H. Ashworth .. 311
Graphical Construction for Resistance Amplifiers, W. A. Barclay 499

Harmful Effects of Inter-electrode Capacity, M. von Ardenne and W. Stoff 509
Harmonic Comparison of Radio-frequencies by the Cathode-Ray Oscillograph, T. S. Rangachari 264
Heaviside Operator and the Operational Calculus, W. A. Barclay 431
H.F. Amplifiers (Patents) 355
High-resistance Couplings (Patents) 536

Indirectly Heated Valves (Patents) 697
  Inductance, Mutual, in Radio Circuits, L. Hartshorn 184
Inductance and Capacity of an Aerial, Equivalent (Editorial) 297
Inductance and Capacity of an Aerial with Inserted Coil or Condenser (Editorial) .. 357
  (Correspondence) 384
INSTITUTION OF ELECTRICAL ENGINEERS, *Papers Read :*
  The Attenuation of Wireless Waves over Land, R. H. Barfield 25
  Rotating-Beacon Radio Transmitters (*Abstracts from 3 Papers*), T.H.Gill, N. F. G. Hecht, R. L. Smith-Rose, S. R. Chapman 85

PAGE

  The Design and Distribution of Wireless Broadcasting Stations, P. P. Eckersley .. 189
  Some Practical Applications of Quartz Resonators, G. W. A. Cobbold and A. E. Underdown 215
  The Study of Signal Fading, Prof. E. V. Appleton 267
  Screened-grid Valves (Discussion) 335
  The Washington Convention (Chairman's Address) 666
Inter-Electrode Capacities and Resistance Amplification, L. Hartshorn 419
Inter-Electrode Capacity, Balancing (Patents) 535
Interference, Balancing out (Patents) 47
Interference Eliminators (Patents) 235
Interfering Oscillations in a Supersonic-Heterodyne Receiver, R. L. Smith-Rose 673
Intervalve Coupling (Patents) 355, 475

JENNINGS, J. K. :
  Valve Current from A.C. Mains 77

Land-line and Radio Signals, Combined (Patents) 414
Light-Sensitive Cells (Patents) 109
Loop Permeability in Iron, and the Optimum Air Gap in an Iron Choke, A. A. Symonds 485
  (Correspondence) 593
Loud Speaker (Correspondence) .. 594, 636
Loud Speaker Diaphragm (Patents) .. 475, 699
Loud Speaker, Moving Coil Drive, Output Power Measurements, H. A. Clark and N. R. Bligh 491
Loud Speaker Substitute (Patents) 293
Loud Speakers (Patents), 110, 354, 416, 534, 595, 597, 653, 700
Low-frequency Choke Amplifier Performance, Graphical Estimation of 660
Low-frequency Amplifiers (Patents) 536
Luminous Crystal Oscillators (Patents) .. 413
Luminous Frequency-Indicators (Patents) .. 107

Main Unit, H.T., with Glow Discharge Rectifier, German 251
Mains, A.C., Valve Current from, J. K. Jennings 77
Mains-fed Receiver (Patents) 295
Mains-Supply Units (Patents) .. 111, 174, 596
Marconi 100 Watt Telephony Set, XMB1 .. 360
Marconi Short-wave Transmitting Valve .. 370
Mass-production Sets (Patents) 476
Measurement of Large Radio-frequency Currents, Application of Condensers, P. R. Coursey 565
Measurement of Small Variable Capacities at Radio Frequencies, W. H. F. Griffiths .. 452
Metal Rectifiers (Patents) 352
Meters, A New Range of 131
Microphone Amplifiers and Transformers, H. L. Kirke 361, 443
Microphones (Patents) 46
Modulation by Phase-Displacement (Patents) 236
Multi-electrode Valves (Patents) 416
Multi-stage Valves (Patents) 533, 654

U OF M BINDERY NOV 1 1929

453093

PAGE
Multiple-stage Valve Sets (Patents) 356
Mutual Inductance in Radio Circuits, L. Hartshorn 184

National Physical Laboratory, Annual Visit 498
New Method of Using Resistance Amplification with Screened Grid Valves, J. J. Dowling 61
New Naval Apparatus (Marconi Receiver) 303
Neutralising Capacity Effects (Patents) 596
Neutralising Space Charge (Patents) 174
Novel Valve Detector, H. J. Neill 74

Olympia Radio Show, 1928, (Editorial) 537
Olympia Radio Show, 1928, Scientific Instruments at 620
Oscillation, The Power in a Modulated, E. H. Robinson 252
Oscillations, Parasitic H.F. Damping out (Patents) 47
Oscillations, Parasitic, In the Case of a Tuned-Anode Oscillator, M. Reed 135
Oscillators, Luminous Crystal (Patents) 413
Oscillators, Piezo-controlled (Patents) 48
Oscillograph Equipment, Portable, for the Observation of Transient Electrical Phenomena, P. R. Coursey 616
Output Power Measurements on a Moving-Coil Drive Loud Speaker, H. A. Clark and N. R. Bligh 491
(Correspondence) 594, 636

Parallel, Valves in (Correspondence) 42, 282
Parasitic Oscillation (Patents) 233
PATENTS, SOME RECENT, 45, 107, 171, 233, 293, 352, 413, 474, 531, 595, 652
PCJJ, Fading Measurements in India. T. S. Rangachari 501
PCJJ, Holland's Short-wave Station (Illustration) 134
Physical Society's Exhibition 94
Piezo-controlled Oscillators (Patents) 48
Piezo-controlled Valve Generators (Patents) 173
Photo-Electric Amplifiers (Patents) 597
Photo-Electric Cells (Patents) 699
Photo-Electric Modulation (Patents) 353
Photo-Electric Modulators (Patents) 356
Photo-Electric " Pick-ups " (Patents) 474
Photo-Electric Relays (Patents) 533
Photo-Electric Valve Amplifier (Patents) 234
Picture Telegraphy (Patents) 655
Pictures, Transmitting (Patents) 413
Piezo-controlled Oscillators (Patents) 598
Piezo-Crystal Receivers (Patents) 293
Piezo-Crystals, Mounting (Patents) 414, 655
Piezo-Effects, Mechanical (Patents) 171
Piezo-Electric Control (Patents) 236
Piezo-Electric Vibrations, Utilizing (Patents) 48
Polar Diagrams due to Plane Aerial Reflector Systems, T. Walmsley 575
(Correspondence) 636
Potential Difference and Capacity in A.C. Problems (Editorial) 113

PAGE
Potential Difference, Some Further Problems (Editorial) 175
Power Factor and Capacity of the Electrodes and Base of Triode Valves 16
Power in a Modulated Oscillation, E. H. Robinson 252
Projector, Flat, The Theory of (Correspondence) 43
Protecting Transformers (Patents) 354
Push-Pull H.F. Amplification (Patents) 415

Quality *versus* Selectivity in Distant Broadcasting Reception (Editorial) 417
Quartz Oscillators (Patents) 108
Quartz Resonators, Some Practical Applications (*I.E.E. Paper*), G. W. A. Cobbold and A. E. Underdown 215
Quartz Resonators (Patents) 652

Radiation Resistance and Energy Capacity of Half-wave Aerials, E. Green 82
(Correspondence) 284
Radiation, Short-wave (Patents) 656
Radio Measurements, A Chapter in the History of (Editorial) 477
Radio Signal Measurement, Some Methods of, K. Sreenivasan 205, 273
RADIO SOCIETY OF GREAT BRITAIN:
Annual Convention (Photograph) 600
Reactance and Admittance Curves, L. T. Bird 327, 371
Reactive Resistance-Couplings (Patents) 532
Receivers, Long and Short Range (Patents) 653
Reception, Long-distance, The Effect of Weather Conditions on, S. K. Lewer 152
Rectification as a Criterion of Distortion in Amplifiers, M. von Ardenne 52
Rectifier, Copper-Oxide (Editorial) 1
Rectifier, Dual-Supply (Patents) 171
Rectifiers, Dry Contact (Patents) 652
Rectifiers, Gas-filled (Patents) 173, 598
Rectifiers (Patents) 110
Rectifiers, Metal (Patents) 352
Rectifying Installations (Patents) 295
Reflecting Layer of the Upper Atmosphere, G. H. Munro 242
Reflex Voltmeter, Further Notes on, W. B. Medlam and U. A. Oschwald 56
Regenerative Resistance Couplings (Patents) 235
Remote Control Systems (Patents) 698
Re-Radiation, Preventing (Patents) 699
Resistance Amplification and Inter-Electrode Capacities, L. Hartshorn 419
Resistance Amplification, New Method of using, with Screened Grid Valves, J. J. Dowling 61
(Correspondence) 284, 513
Resistances of Grid Leak Type, Effect of Frequency on, W. Jackson 677
Resonance Curves of Coupled Circuits, Prof. E. Mallett 437
Retro-action in Amplifiers, H. A. Thomas 245
(Correspondence) 385
Rotating-Beacon Radio Transmitters (*I.E.E. Papers, Abstracts*), T. H. Gill, N. F. G. Hecht, R. L. Smith-Rose, S. R. Chapman 85

PAGE
Scientific Instruments at Olympia 620
Screened-Grid Amplifiers (Patents) .. 413
Screened-grid Valve, Approximate Theory of, B. C. Brain.. 179
Screened-Grid Valves, New Method of using Resistance Amplification, J. J. Dowling 61
(Correspondence) 284, 513
Screened-grid Valves (*I.E.E. Discussion*) .. 335
Screened-Grid Valves (Patents) .. 110, 293
Selective Couplings (Patents) 233
Selective Reception (Patents) 296
Self-induction of Single-turn Circuits of Various Shapes (Editorial) 238
Shielded-grid Valves (Patents).. 233
Short Radio Waves, Some New Applications of, J. and W. Taylor 503
Short-wave Aerial Systems, E. Green 304
(Correspondence) 513
Short-wave Fading (Correspondence).. .. 635
Short-wave Radiation (Patents) 656
Short-wave Signalling (Patents) .. 353, 476
Short-wave Transmitting Valve (D.E.T.1.SW) 370
Signal Fading, The Study of (*I.E.E. Paper*), Prof. E. V. Appleton 267
Signal Measurement, Some Methods of, K. Sreenivasan 205, 273
Signal Strength Control (Patents) 111
Single-wave Broadcasting (Patents) 536
Smoothing Circuits (Patents) 45
Spot-welded Thermojunctions.. 314
Stabilised Tetrode Circuit (Patents) 698
Stabilising Amplifiers (Patents) 352
Stabilising Circuits (Patents) 172
Stability of the Tuned-grid Tuned-plate H.F. Amplifier, R. T. Beatty 3
(Errata) 112, 147
Static, System for Combating Effects of, T. A. Tubbs 378
Station, Holland's Short-wave, PCJJ (Illustration) 134
Substandard Wavemeter Design, W. H. F. Griffiths 324
Superheterodyne, A Double 669
Supersonic-Heterodyne Receiver, Interfering Oscillations in 673
Supersonic Receivers (Patents) 697
Surges in Eliminator Smoothing Circuits 601, 680
Switch-controlled Receiver (Patents) .. 293
Symbolical Algebra (Editorial) 237
Symbolical Algebra, J. A. Ratcliffe 239
(Correspondence) 340

Telephone Set, Marconi 100-watt XMB 1 .. 360
Television Apparatus (Patents), 475, 531, 595, 656
Television by Invisible Rays (Patents) .. 656
Television (Correspondence) 680
Television Rectifiers (Patents).. 653
Television Systems (Patents) .. 107, 353, 698
Tetrode Circuit, Stabilised (Patents) 698
Thermojunctions, Spot-welded 314
Theory of the Flat Projector (Correspondence) 43
Torusolenoid (Patents).. 171
Transformers and Microphone Amplifiers, H. L. Kirke 361, 443
Transformers, Protecting (Patents) 354

PAGE
Transmitters, Valve (Patents).. 595
Transmitting Station, Waves of Definite Frequency but Varying Amplitude (Correspondence) 635, 682
Tuner, A Flexible (Patents) 112

Ultra High Frequencies, Handling (Patents) 234
Ultra High-Frequency Generators (Patents) 294
Upper Atmosphere, Radio Transmission and the (Editorial) 657

Valve Characteristics, The Application of Alignment Charts to, M. Reed 571
Valve, Four-Electrode, Characteristic Curves, N. R. Hall 198
Valve, The Frenotron 214
Valve, Short-wave Transmitting (D.E.T.1.SW) 370
Valve Current from A.C. Mains, J. K. Jennings 77
Valve Detector, A Novel, H. J. Neill 74
Valve-Detector, A New Idea for 515
Valve Filaments, A.C. (Patents) .. 111, 172
Valve Filaments, The Use of A.C. Current for Heating, C. W. Oatley 380
Valve Tester, Direct Reading, M. G. Scroggie 480
Valve Transmitters (Patents) 595
Valves in Parallel, The Performance of (Correspondence 42, 220, 282
Valves as High-Frequency Generators (Patents) 172
Valves, Four-Electrode (Patents) 296
Valves, Multi-Electrode (Patents) 416
Valves, Multi-Stage (Patents) 533, 654
Valves, Paralleled, Feeding Resistive Loads, W. Baggally 315
Valves, Screened-grid, Approximate Theory of, B. C. Brain 179
Valves, Screened-grid (*I.E.E. Discussion*) .. 335
Valves, Screened Grid, Resistance Amplification with, J. J. Dowling 61
Valves, Screened-grid (Patents) .. 110, 233
Valves, Triode, The Power Factor and Capacity of the Electrodes and Base 16
Voltage Regulation in H.T. Eliminators (Patents) 532
Voltmeter, Reflex, Further Notes on, W. B. Medlam and U. A. Oschwald 56
Volume Control, Automatic (Patents) .. 414

Washington International Radiotelegraphic Convention (*I.E.E.* Chairman's Address) 666
Wavelengths, Allocation of European Broadcast, Siffer Lemoine 386
Wavemeter Condenser, A New Precision, W. H. F. Griffiths 278
Wavemeter Design, Substandard, W. H. F. Griffiths 324
Wavemeters, Precision, The Accuracy and Calibration Performance of Variable Air Condensers for, W. H. F. Griffiths 17, 63
Waves, Wireless, Attenuation over Land (*I.E.E. Paper*), R. H. Barfield 25
Weather Conditions, Their Effect on Long-distance Reception, S. K. Lewer.. .. 152
Wired Wireless (Patents) 652
Wiring Systems (Patents) 697

II. INDEX TO AUTHORS.

PAGE
Allen, R. G. .. 259
Appleton, Prof. E. V. (*I.E.E. Paper*) .. 267
Ashworth, M. H. .. 311
Baggally, W. .. 315
Barclay, W. A. .. 211, 431, 499, 660
Barfield, R. H. (*I.E.E. Paper*) .. 25
Beatty, R. T. .. 3, 300
Bird, L. T. .. 327, 371
Bligh, N. R., and Clark, H. A. .. 491
Brain, B. C. .. 179
Chapman, S. R. (*I.E.E. Paper*) .. 88
Clark, H. A., and Bligh, N. R. .. 491
Cobbold, G. W. A. (*I.E.E. Paper*) .. 215
Colebrook, F. M. .. 538
Coursey, P. R. .. 565, 616
Dowling, J. J. .. 61
Eckersley, P. P. (*I.E.E. Paper*) .. 189
Edgeworth, Lt.-Col. K. E. .. 148
Gill, T. H. (*I.E.E. Paper*) .. 85
Green, E. .. 82, 304
Griffiths, W. H. F. .. 17, 63, 278, 324, 452
Hall, N. R. .. 198
Hartshorn, L. .. 184, 419
Hecht, N. F. G. (*I.E.E. Paper*) .. 85
Howe, Prof. G. W. O. .. 49
Inglis, C. C. .. 132
Jackson, W. .. 255, 677
Kirke, H. L. .. 361, 443

PAGE
Lemoine, S. .. 386
Lewer, S. K. .. 152
Mallett, Prof. E. .. 437
Medlam, W. B. .. 56, 545
Munro, G. H. .. 242
Neill, H. J. .. 74
Oatley, C. W. .. 380
Oschwald, U. A. .. 56
Ramsey, J. F. .. 669
Rangachari, T. S. .. 264, 501, 633
Reed, M. .. 135, 322, 571
Robinson, E. Howard .. 252
Scroggie, Marcus G. .. 480
Smith-Rose, R. L. (*I.E.E. Paper*) .. 88, 673
Sowerby, A. L. M. .. 201
Stoff, W., and M. von Ardenne .. 509
Sreenivasan, K. .. 205, 273
Symonds, A. A. .. 485
Taylor, J. and W. .. 503
Thomas, H. A. .. 245
Tubbs, E. A. .. 378
Underdown, A. E. (*I.E.E. Paper*) .. 215
Von Ardenne, M. .. 52, 509, 556
Walmsley, T. .. 575
Warren, A. G. .. 601
Watt, R. A. Watson (*Abstract of B.A. Paper*) 629
Wilmotte, R. M. .. 119, 538, 607
Zickner, Dr. G. .. 280

III. ABSTRACTS AND REFERENCES.

PROPAGATION OF WAVES.

Aircraft, Short Waves for. See Miscellaneous.

On the **Anomalous** Dispersion and Absorption of Electric Waves.—S. Mizushima, **p. 164.**

Über das Verhalten der Radiotelegraphischen Wellen in der Umgebung des Gegenpunktes der Antenne und Über die Analogie zu den Poissonschen Beugungserschienungen (The behaviour of radio telegraphic waves in the neighbourhood of the **antipodal** point of the antenna, and the analogy to the Poisson diffraction effect).—J. Gratsialos, **p. 637.**

ariations of **Atmospheric Pressure'** as a possible Contributing Cause of Static of Earth Currents and their Variations, and of Variations on the Earth's Magnetic Field.—R. Hamer, **p. 221.**

he **Attenuation** of Wireless Waves over Land.—R. H. Barfield, **p. 285.**

he **Attenuation** of Wireless Waves over Land.—R. H. Barfield, **p. 100.**

ie Störung des elektromagnetischen Feldes eines Senders durch Gebäude und ähnliches (The disturbance of the electromagnetic field of a transmitter by **buildings,** etc.).—S. Klimke, **p. 97.**

ong-wave Radio Receiving Measurements at the **Bureau of Standards** in 1927.—L. W. Austin, **p. 683.**

eviation of Wireless Waves at a **Coastal Boundary, p. 162.**

he **Diamagnetic Layer** of the Earth's Atmosphere and its Relation to the Diurnal Variation of Terrestrial Magnetism.—Ross Gunn, **p. 578.**

nfluence des Surfaces de Discontinuité Atmosphériques sur la Propagation des Ondes Courtes (Influence of the atmospheric surfaces of **discontinuity** on the propagation of short waves).—G. Henri Huber, **p. 101.**

ur Theorie der Lichtzerstreuung in der Erd-Atmosphäre (The Theory of Light **Dispersion** in the Earth's Atmosphere).—J, J. Tichanowsky, **p. 578.**

opagation of Short Waves during a Solar **Eclipse.**—E. J. Alway, **p. 100.**

bservations pendant l'Eclipse du 29 Juin (Observations during the **eclipse** of 29th June).—A. Nodon, **p. 31.**

mpte Rendu des Observations Faites Pendant l'Eclipse de Soleil du 29 Juin, 1927 (Report of the observations made during the sun's **eclipse,** 29th June, 1927).—H. S. Jelstrup, p. **162.**

Milieu Ethéré (On the **ether** medium).—L. Garrigue, **p. 32.**

asurement of **Fading, p. 397.**

-operative Measurements of Radio **Fading** in 1925.—J. Dellinger, C. Jolliffe, and T. Parkinson, **p. 221.**

er Beobachtungen Regelmässiger Schwunderscheinungen in Zusammenhang Mit Schwankungen der Sendefrequenz Bei Kurzen Wellen (Observations of regular **fading** effects connected vith variations in transmitter frequency in short-wave transmission).—Eppen, Scheibe and Weight, **p. 461.**

ding on Short Waves at Long Distances.—E. Gherzi, **p. 637.**

e Study of Signal **Fading.**—E. V. Appleton, **p. 578.**

e Study of Signal **Fading, p. 341.**

rmans Overcome Radio **Fading, p. 684.**

ssungen der elektromagnetischen Feldstärke zur Bestimmung ler Reichweite eines Rundfunksenders (Measurements of electromagnetic **field-strength** to determine the range of a broadcast ransmitter), **p. 99.**

Radio **Field Strength** Survey of Philadelphia.—K. McIlwain nd W. Thompson, **p. 222.**

gramme des Champs Electriques Mesurés à Meudon pendant début de l'Année 1926 (Graphs of electric **fields** measured at leudon during the first part of 1926).—**p. 31.**

lio Transmission **Formulæ.**—G. W. Kenrick, **p. 578.**

les Propriétés Diélectriques des Émulsions Gazeuses (Dielectric roperties of **gaseous emulsions**).—C. Pawlowski, **p. 516.**

uence de la Nature du Sol sur l'Emission et la Reception Radioectriques (Influence of the nature of the **ground** on wireless ansmission and reception).—L. Bouthillon, **p. 162.**

surements of the Effective **Heights** of the Conducting Layer nd the Disturbances of 19th August, 1927.—O. Dahl and L. ebhardt, **p. 285.**

ctive **Heights** of the Kennelly-Heaviside Layer in December, 927, and January, 1928.—Breit, Tuve and Dahl, **p. 683.**

lies of **High-frequency** Radio Wave Propagation.—A. Hoyt aylor and L. C. Young, **p. 460.**

nistrahlung von Horizontal-Antennen (Space Radiation from **orizontal** Antennæ).—A. Meissner, **p. 100.**

r die Bestimmung des Günstigsten Ausstrahlwinkels bei Hori- ntalen Antennen (Determination of the optimum projection gle for **horizontal** aerials).—Meissner and Rothe, **p. 637.**

ation of the Upper Atmosphere.—E. O. Hulburt, **p. 397.**

ation in the Upper Atmosphere.—E. O. Hulburt, **p. 221.**

l'Interprétation de Résultats Expérimentaux relatifs aux opriétés Diélectriques des Gaz Ionisés (On the interpretation some experimental results concerning the dielectric properties **ionised** gases).—H. Gutton, **p. 222.**

Experiments and Observations concerning the **Ionised** Regions of the Atmosphere.—R. A. Heising, **p. 222.**

Seasonal Variation in Signal Strengths of the 20-metre Wave from Nauen in **Japan.**—T. Nakagami and T. Ono, **p. 683.**

Discussion on **Long-distance** Receiving Measurements at the Bureau of Standards in 1925 (L. W. Austin).—K. Sreenivasan, **p. 100.**

Discussion on **Long Distance** Radio Receiving Measurements at the Bureau of Standards in 1925 (L. W. Austin).—B. H. Kynaston, **p. 285.**

La Précision des Mesures et son Contrôle dans L'Opération des Longitudes Mondiales (The Precision of Measurement, and its Control, in the Determination of World **Longitudes**).—A. Lambert, **p. 516.**

Concerning **Lunar** Effects on Electromagnetic Waves.—Greenleaf Pickard, **p. 637.**

L'État Magnétique de la Terre (The Earth's **Magnetic** Condition).—J. Granier, **p. 637.**

The Influence of the Earth's **Magnetic** Field on Wireless Transmission.—E. V. Appleton, **p. 683.**

The Daily Terrestrial **Magnetic** Variations ; and the Sun's Magnetic Field.—S. Chapman, **p. 683.**

On the Diffraction of the **Magnetic Electron.**—C. G. Darwin, **p.683.**

Recent Research in Greenland on Terrestrial **Magnetism.**—de la Cour, **p. 578.**

Radio Communication.—G. **Marconi, p. 222.**

The **Measurements** of the Field Intensities of some High Power Long Distance Radio Stations. Part I.—Bolinas and Bordeaux.—E. Yokoyama and T. Nakai, **p. 683.**

Oscillographic Observations on the Direction of Propagation and Fading of Short Waves.—H. T. Friis, **p. 461.**

The Effect of **Ozone** on the Temperature of the Upper Atmosphere.—E. H. Gowan, **p. 683.**

Long Wave Radio Reception and Atmospheric **Ozone.**—K. Sreenivasan, **p. 683.**

Étude de la Couche d'Ozone de la Haute Atmosphère Pendant la Nuit (Investigation of the layer of **ozone** in the upper atmosphere during the night).—D. Chalonge, **p. 285.**

Étude des Fluctuations Nocturnes de l'Ozone Atmosphérique (Night fluctuations in atmospheric **ozone**).—D. Chalonge, **p. 517.**

Observations on the Height of the **Ozone** in the Upper Atmosphere —Gôtz and Dobson, **p. 517.**

The Propagation of Radio Waves along the Surface of the Earth and in the Atmosphere, by Professor P. O. **Pedersen.**—J. C. Rybner, **p. 222.**

Polarisation of Radio Waves.—J. Hollingworth and R. Naismith, **p. 163.**

On a Method of Determining the State of **Polarisation** of Downcoming Wireless Waves.—E. V. Appleton and J. A. Ratcliffe, **p. 221.**

The **Polarisation and Fading** of Short Wireless Waves.—T. L. Eckersley, **p. 397.**

The **Polarisation** of Radio Waves.—J. Hollingworth, **p. 460.**

Propagation Around the Earth, **p. 341.**

Über die Fortpflanzung elektromagnetischer Wellen (On the **propagation** of electromagnetic waves).—H. Benndorf and A. Székely, **p. 341.**

Observations et Travaux Récents sur la Propagation des ondes Électromagnétiques (Observations and recent work on the **Propagation** of electromagnetic waves).—R. Mesny, **p. 460.**

Zur Theorie der Ausbreitung Elektromagnetischer Wellen Längs der Erdoberfläche (The **Propagation** of Electromagnetic Waves over the Earth's Surface).—R. Weyrich, **p. 516.**

Les Phénomènes de Propagation des Ondes Radiotélégraphiques (The phenomena of **propagation** of radio-telegraphic waves).—R. Jouast, **p. 578.**

The Lorentz **Reciprocity** Theorem for Electric Waves.—Stuart Ballantine, **p. 341.**

The **Reflecting Layer** of the Upper Atmosphere.—G. H. Munro, **p. 341.**

On the **Refraction** of Electro-Magnetic Waves in a Spherically Stratified Medium.—T. Y. Baker, **p. 81.**

Report of the Chairman of the Commission on Radio Wave Propagation, International Union of Scientific Radio Telegraphy.—L. W. Austin, **p. 285.**

On **Round the World** Signals.—E. O. Hulburt, **p. 285.**

The **Scattering** of Wireless Waves.—T. L. Eckersley, **p. 221.**

The Propagation of **Schrödinger** Waves in a Uniform Field of Force.—G. Breit, **p. 637.**

Propagation des Ondes Courtes Autour de la Terre (Propagation of **Short Waves** round the Earth).—J. Reyt, **p. 462.**

Diurnal Variation in Signal Strengths of **Short Waves.**—T. Nakagami and T. Ono, **p. 683.**

A Note on the **Short Wave** Long Distance Transmission.—T. Minohara and K. Tani, **p. 683.**

Suite d'une Etude sur la Propagation des Ondes Courtes (Con-

tinuation of an investigation on the propagation of **short waves**).—M. Lardry, **p. 31.**
Correlation of Long Wave Transatlantic Radio Transmission with other Factors affected by **Solar Activity.**—C. N. Anderson, **p. 285.**
On the Influence of **Solar Activity** on Radio Transmission.—L. Austin and I. Wymore, **p. 221.**
Relation entre les Oscillations Régulières des Champs Electriques et Magnetiques Terrestres, et les Foyers Solaires Diamétraux (The relation between the regular oscillations of the terrestrial electric and magnetic fields and the diametrical **solar foci**).—A. Nodon, **p. 341.**
Une Recrudescence Importante des Taches Solaires dans la Deuxième Quinzaine de Février, 1928 (Significant renewed activity of **sun spots** in the last fortnight of February, 1928).—H. Memery, **p. 285.**
Note on **Total Reflection** of Electric Waves at the Interface between Two Media.—H. M. Macdonald, **p. 516.**
A **Transmitter-modulating** Device for the Study of the Kennelly Heaviside Layer by the Echo Method.—Tuve and Dahl, **p. 516.**
Further Measurements on Wireless Waves received from the **Upper Atmosphere.**—R. L. Smith-Rose and R. H. Barfield, **p. 31.**
A Theory of the **Upper Atmosphere** and Meteors.—H. B. Maris, **p. 222.**
Sur la Vitesse de Propagation des Ondes Radiotélégraphiques (On the **velocity** of propagation of radio waves).—A. Lambert, **p. 285.**
The Effect of **Weather** Conditions on Long-distance Reception.—S. K. Lewer, **p. 221.**
Wave Propagation and the **Weather.**—F. Charman, **p. 31.**
Woods and Wireless.—R. H. Barfield, **p. 462.**
Woods and Wireless.—B. Rolf, **p. 341.**

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

Notes on **Aperiodic Amplification** and Application to the Study of Atmospherics.—A. Hund, **p. 638.**
Present State of Knowledge of **Atmospherics.**—R. A. Watson Watt, **p. 685.**
The Present State of our Knowledge on **Atmospherics.**—R. A. Watson Watt, **p. 684.**
Relations entre les parasites atmosphériques et les phénomènes météorologiques. (Relation between **atmospherics** and meteorological phenomena.)—R. Bureau, **p. 684.**
The **Aurora** and Its Spectrum.—J. C. McLennan, **p. 638.**
Atmospherics at Watheroo, Western **Australia.**—J. E. Cairns, **p. 101.**
An **Automatic Recorder** for Measuring the Strength of Radio Signals and Atmospheric Disturbances, **p. 463.**
Über die Hypothese, Dass die Höchsten Atmosphärenschichten Durch Beta-Strahlen Erwärmt Werden (The hypothesis that the highest layers of the atmosphere are heated by **β-rays**).—H. Petersen ; reply by W. Anderson, **p. 518.**
Carriers of Electricity in the Atmosphere.—A. M. Tyndall, **p. 517.**
Elektrische Leitfähigkeit der Atmosphäre und Kondensationskernzahl (Electrical **Conductivity** of the Atmosphere and Condensation Nucleus Numbers).—J. Scholz, **p. 684.**
Sur la Loi de Constitution de l'Atmosphère (The law of atmospheric **constitution**).—Esnault-Pelterie, **p. 579.**
A Note on **Corona** at High Humidity.—A. W. Simon, **p. 462.**
Sur la Loi de Variation de Densité de L'Atmosphère en Fonction D'Altitude (The Law of Variation of the **density** of the atmosphere as a function of the altitude).—Esnault-Pelterie, **p. 517.**
Méthode Pratique de Calcul de la Rigidité Diélectrique de l'Air (A practical method of calculating the **dielectric strength** of air).—G. Devillez, **p. 579.**
Die Erhaltung der Erdladung durch den Blitzstrom (The Maintenance of the **Earth's** Charge by Lightning Currents).—A. Wigand, **p. 637.**
The **Earth's** Electric Charge.—W. F. G. Swann, **p. 342.**
A New Arrangement for showing the Diurnal Variation in the Intensity of the **Earth's Surface Charge** at a Given Place.—F. Sanford, **p. 637.**
Observations on Atmospheric Electrical Conductivity in Connection with the Solar **Eclipse** of June 29th, 1927.—Nolan and O'Brolchain, **p. 463.**
Système Antiparasite Marrec (The Marrec system for **eliminating** atmospherics).—Y. Marrec, **p. 32.**
Electric Potential Gradient Measurements at **Eskdalemuir,** 1913–23.—R. A. Watson, **p. 579.**
La Prévision des Cyclones de la mer des Antilles et du Golfe du Mexique (**Forecasting** cyclones).—Laforest Duclos, **p. 518.**
The Directional Observations on Atmospherics in **Japan.**—E. Yokoyama and T. Nakai, **p. 684.**
High Voltages from the Atmosphere, **p. 462.**
On the Sources of Atmospherics Received in **Japan.**—J. Obata, **p. 579.**
On Thunderstorms in **Japan** and Recent Theories of Thunder Electricity.—S. Fujiwara, **p. 579.**
Observations sur les Perturbations Atmospheriques dans les Îles Kouriles Septentrionales (Atmospherics in the N. **Kurile** Islands).—Nagashima and Matsudaira, **p. 579.**
Some Electrophysical Conditions Determining **Lightning** Surges.—H. Norinder, **p. 516.**
Sur L'Ionisation Intense de l'Air dans les Lieux Fréquemment Foudroyés (Intense ionisation of the air in spots frequently struck by **lightning**).—Dauzère and Bouget, **p. 517.**
Progressive **Lightning.**—C. V. Boys, **p. 638.**
Changes in the Electric Field due to **Lightning** Discharges.—J. Jensen, **p. 223.**
Einige Untersuchungen Über den Blitz (Some investigations into **Lightning-flashes**).—L. Binder, **p. 397.**
On the Quantity of Electricity Discharged in a **Lightning** Stroke.—A. W. Simon, **p. 517.**
Zur Frage nach der Natur der Kugelblitze (The Nature of Globular **Lightning**).—K. F. Bottlinger, **p. 684.**
Wirkung Eines Blitzschlages (The Effect of a **Lightning-stroke**).—F. Janetzky, **p. 637.**
Rendering Visible a **Magnetic Field.**—Elihu Thomson, **p. 579.**
The Value of **Magnetic** Investigations in New Zealand and Samoa.—C. Chree, **p. 685.**
Sur l'Orage Magnétique du 7 au 8 Juillet, 1928 (The **Magnetic Storm** of 7th–8th July, 1928).—Ch. Maurain, **p. 638.**
Magnetic Storms.—A. H. R. Goldie, **p. 685.**
Atmospheric **Measurements** at the Shuan-Chiao Radio Station.—Kinase, Maeda and Saito, **p. 578.**
Wireless and **Meteorology, p. 102.**
Methods of Reducing the Effect of Atmospheric Disturbances.—E. H. Armstrong, **p. 164.**
Some Recent Work on the Light of the **Night Sky** (Part I.).—Rayleigh, **p. 638.**
Radio Reception and **Northern Lights, p. 638.**
Radioaktive Niederschläge auf Hochantennen (**Radioactive** deposit on high antennæ).—F. Schindelhauer, **p. 518.**
The **Range** of Atmospherics, **p. 101.**
The **Reduction** of Atmospheric Disturbances.—J. R. Carson, **p. 579.**
La Rèsonance et les Atmosphériques (**Resonance** and atmospherics).—H. de Bellescize, **p. 32.**
Zur Frage der Periodizität der Seismischen und Vulkanischen Erscheinungen (The periodicity of **seismic** and volcanic phenomena).—W. B. Schostakowitsch, **p. 638.**
Relations Entre la Propagation des Ondes Électromagnétiques, l'Activité Solaire et l'État Atmosphérique (Relations between the propagation of electromagnetic waves, **solar activity** and the condition of the atmosphere).—A. Nodon, **p. 462.**
The Correlation of **Solar and Terrestial** Magnetic Phenomena.—S. Chapman, **p. 517.**
Anfangspannungen für Mehrfach Elektroden in Luft (Initial **sparking** voltages for multiple-electrodes in air, **p. 397.**
Observation, Enregistrement et Prévision des Orages an moyen des Ondes électriques (Observation, recording and forecasting of **Storms** by Electric Waves).—A. Turpain, **p. 684.**
The Fields of Force in the Atmosphere of the **Sun.**—A. Buss, **p. 32.**
The **Sun's** Outer Atmosphere.—E. A. Milne, **p. 462.**
La Sismicité du Soleil et la Périodicité des Orages Magnétiques (The **sun's "seismicity"** and the periodicity of magnetic storms).—E. Belot, **p. 223.**
Sun-Spot Numbers and Annual Rainfall in New Zealand.—E. Kidson, **p. 685.**
The Relation of Radio Reception to **Sunspot** Position and Area.—G. W. Pickard, **p. 101.**
Large Magnetic Storms and Large **Sunspots.**—Greaves and Newton **p. 579.**
The Polarity of **Thunderclouds** and the Interchange of Electricity between Thunderclouds and the Earth.—B. F. J. Schonland, **p. 684.**
The Electrostatics of the **Thunderstorm.**—A. W. Simon, **p. 32.**
The Mechanism of **Thunderstorms, p. 685.**
Atmospherics and **Transatlantic** Telephony.—A. G. Lee, **p. 32.**
The **Upper Atmosphere.**—J. Bartels, **p. 517.**
The Raman Effect and the Spectrum of the **Zodiacal Light.**—L. A. Ramdas, **p. 517.**

PROPERTIES OF CIRCUITS.

La Question **d'Amplification.** II. La Rétroaction.—P. Olinet, **p. 579.**
Zur Theorie der Endverstärkung (Theory of **last stage amplification**).—M. von Ardenne, **p. 164.**
Zur Niederfrequenzverstärkung mit Drosselspulenkopplung (**Low** frequency **amplification** with choking-coil coupling).—H. Kafka, **p. 398.**
Über die Spannungsverstärkung Mittels Transformatorenkopplung beim Niederfrequenzverstärker (Voltage **amplification** by Transformer-coupling in L.F. Amplifiers).—H. Reppisch, **p. 580.**
Resistance **Amplifiers.**—P. Tyers, **p. 102.**
Sur une Nouvelle Méthode d'Amplification des Courants Alternatifs à Haute Fréquence (A new method of **amplifying** H.F. currents).—J. Bethenod, **p. 518.**
Effect of **Anode-grid Capacity** in Detectors and L.F. Amplifiers.—W. B. Medlam, **p. 640.**
Effect of the **Antenna** in Tuning Radio Receivers and Methods of Compensating for It.—Sylvan Harris, **p. 639.**
Notes on **Aperiodic** Amplification and Application to the Study of Atmospherics.—A. Hund, **p. 639.**

Quantitaves zur Audiongleichrichtung (Quantitative Measurements on **Audion**-rectification).—M. v. Ardenne, **p. 685.**
Back Coupling in L.F. Amplifiers.—M. G. Scroggie, **p. 102.**
Ein experimenteller Beitrag zum Spulenproblem (An experimental contribution to the **coil** problem).—R. Rücklin, **p. 686.**
Gekopplete Kreise (**Coupled** circuits).—W. Kummerer, **p. 164.**
The Resonance Curves of **Coupled Circuits.**—E. Mallett, **p. 640.**
A Vector Loci Method of Treating **Coupled** Circuits.—E. Mallett, **p. 165.**
Über Stromverhältnisse in einem induktionsfreien Widerstand, der parallel zu einem Schwingungskries geschaltet ist (On the **current relations** in an inductance-free resistance, connected in **parallel** with an oscillatory circuit).—D. Doborzynski, **p. 342.**
Damping Due to Grid Current in the Case of a Valve Oscillator.—M. Reed, **p. 463.**
On Banks of Paralleled Valves Feeding Resistive Loads without **Distorting** the Wave Form.—W. Baggally, **p. 463.**
Distortion Correction in Electrical Circuits with Constant Resistance Recurrent Networks.—O. J. Zobel, **p. 579.**
Rectification as a Criterion of **Distortion** in Amplifiers.—M. von Ardenne, **p. 165.**
Über die nichtlineare Verzerrung von Lautsprechern und Fernhörern (On the non-linear **distortion** of loud-speakers and telephones).—E. Meyer, **p. 166.**
Sur la Distorsion Téléphonique et sa Mesure (Telephonic **distortion** and its measurement).—P. David, **p. 584.**
Über den Einfluss der Nichtlinearen Eisen-Verzerrrungen auf die Güte und Verständlichkeit eines Telephonic-Übertraguns-systemes (The influence of non-linear **iron-distortion** on the quality and intelligibility of telephone transmission).—G. V. Békésy, **p. 528.**
On the **Distortionless** Reception of a Modulated Wave and its Relation to Selectivity.—F. Vreeland, **p. 286.**
Discussions on the **Distortionless** Reception of a Modulated Wave and its Relation to Selectivity.—F. K. Vreeland, **p. 343.**
Discussions on the **Distortionless** Reception of a Modulated Wave and its Relation to Selectivity, **p. 464.**
On the **Distortionless** Reception of a Modulated Wave and its Relation to Selectivity, **p. 520.**
Untersuchungen an der Doppelgitterröhre in Raumladungsnetzschaltung (Investigation of **double-grid** valves in space-charge-net connection).—J. Dantscher, **p. 686.**
Über die einem Empfänger durch Erdung zugeführte Energie (The Energy introduced into a Receiver by **Earthing**).—A. Székely, **p. 685.**
ur un Dispositif Électromagnétique de Lampes à Trois Électrodes (An **electro-magnetic** arrangement of three-electrode valves).—J. F. Thovert, **p. 580.**
ur Frage Über die Energieverteilung Zwischen dem Sender und dem Regenerativen Empfänger (The distribution of **energy** between transmitter and regenerative receiver).—G. Ostroumoff, **p. 580.**
ur Theorie der Siebketten (The Theory of **Filter Chains**).—Winter-Günther, **p. 639.**
n Experimental Investigation of **Forced** Vibrations.—L. W. Blau, **pp. 639** and **686.**
pplications Nouvelles des Lampes à Quatre Électrodes (New applications for **four-electrode** valves).—Decaux, **p. 398.**
n **Frequency Variations** of the Triode Oscillator.—D. Martyn, **p. 33.**
ei Beiträge über Schwingungserzengung (Three contributions on the **generation** of oscillation).—G. Jobst, **p. 164.**
Graphical Method of Amplifier Coupling Design.—M. G. Scroggie, **p. 33.**
e Phenomenon of Blocking of Potential of an Insulated **Grid.**—S. A. Obolensky, **p. 518.**
eping **H.F.** out of the L.F. Amplifier.—A. L. Sowerby, **p. 165.**
r abgestimmte Hochfrequenzverstärker (The tuned **high-frequency** amplifier).—W. Runge, **p. 164.**
e Cause and Prevention of **Hum** in Receiving Tubes Employing Alternating Current Direct on the Filament.—W. J. Kimmel, **p. 640.**
e Harmful Effects of **Inter-electrode** Capacity.—v. Ardenne and Stoff, **p. 640.**
er-electrode Capacities and Resistance Amplification.—L. Hartshorn, **p. 640.**
ntribution à l'Etude de la Basse Fréquence (Contribution to the study of **low frequency**).—M. Dupont, **p. 34.**
parate für Verstärkungs-Messungen an Mehrfachröhren oder nderen in Kaskade geschalteten Röhren-Anordnungen (Apparatus for amplification **measurements** on multiple valves or other valve-arrangements connected up in cascade).—F. Gabriel, **p. 64.**
alyse einer Elektrischen Schaltung für das Kondensatormikophon (Analysis of an electrical circuit for the Condenser-**Microphone**).—A. J. Jakowleff, **p. 398.**
d Current **Modulations.**—E. Peterson and C. R. Keith, **p. 223.**
Sujet d'une Méthode Simple de Calcul de l'Inductance de Modulation (On the subject of a simple method of calculating the **modulation** inductance).—C. Krulisz, **p. 34.**
Weiterer Beitrag zur Negadynschaltung (Further contribution on the **negadyne** circuit-arrangement).—E. Mittelmann, **p. 223.**
Les **Neutrodynes.**—S. Lwoff, **p. 34.**
Making **Normal Co-ordinates** coincide with the Meshes of an Electrical Network.—E. A. Guillemin, **p. 33.**
On the Predetermination of **Oscillating** Amplitudes and Circui Constants L, C and M under the Conditions of Maximum Output of Triode Oscillators.—K. Kurokawa and H. Hayakawa, **p. 685.**
Parasitic Oscillations in the Case of a Tuned-Anode Oscillator.—M. Reed, **p. 224.**
Equilibres Instables et Régimes Statiques Parasites dans les Circuits Électriques Associés aux Triodes (Conditions of unstable equilibrium and of **parasitic** disturbances in electric circuits associated with 3-electrode valves).—Podliasky, **p. 580.**
The Suppression of **Parasitic Oscillations** in Valve Circuits.—M. Reed, **p. 33.**
The Relation Between **Plate Current** and Plate Potential in the Thermionic Amplifier, deduced from the Orbital Motion of the Electrons.—L. E. McCarty, **p. 102.**
Reactance and Admittance Curves: Applied to Tuned Circuits with and without Resistance.—L. T. Bird, **p. 463.**
Über den Rückgekoppelten Verstärker (Amplifiers with **Reaction coupling**).—Y. Watanabe, **p. 685.**
Ein Beitrag zur Quantitativen Messung von Empfängern (Contribution to the quantitative measurement of **receivers**).—E. Klotz, **p. 32.**
A Study of the **Rectification** Efficiency of Thermionic Valves at Moderately High Frequencies.—W. E. Benham, **p. 224.**
Über Anodengleichrichtung (On anode **rectification**).—M. von Ardenne, **p. 342.**
The Effect of **Regeneration** on the Received Signal Strength.—Van der Pol, **p. 638.**
Quelques Expériences avec des Triodes et les Oscillations de Relaxation (Some experiments with valves and **relaxation** oscillations).—B. van der Pol and J. van der Mark, **p. 34.**
Stabilisation des Oscillations de Relaxation (Stabilisation of " oscillations of **relaxation** ").—Bedeau and de Mare, **p. 579.**
Le Battement du Cœur considéré comme Oscillation de Relaxation, et un Modèle Électrique du Cœur (Heart-beat as an Oscillation of **Relaxation,** and an Electric Model of the Heart).—B. van der Pol and J. van der Mark, **p. 686.**
Einige Ergänzungen und Berichtigungen zum Problem der Kippschwingungen (Some Amplifications and Corrections on the Problem of **Relaxation** Oscillations).—E. Friedlander, **p. 686.**
Zwei Verstärker mit Ohmscher Rückkopplung in theoretische Behandlung (Two Amplifiers with **Resistance Reaction,** treated theoretically).—F. Schierl, **p. 686.**
Parallel **Resonance** and Anti-Resonance.—W. J. Seeley, **p. 639.**
Resonant Circuits with Reactive Coupling.—R. T. Beatty, **p. 33.**
Chains of **Resonant Circuits.**—E. Mallett, **p. 639.**
Reaction and **Selectivity.**—A. P. Castellain, **p. 102.**
The **Short Wave Limit** of Vacuum Tube Oscillators.—C. R. Englund, **p. 33.**
Some Extensions of Theory and Measurements of **Shot-effect** in Periodic Circuits.—H. B. Vincent, **p. 224.**
The **Stability** of the Tuned-grid Tuned-plate H.F. Amplifier.—R. T. Beatty, **p. 102.**
The **Stability** of a Valve Amplifier with Tuned Circuits and Internal Reaction.—R. T. Beatty, **p. 639.**
On the Values and the Effects of **Stray Capacities** in Resistance-coupled Amplifiers.—M. von Ardenne and W. Stoff, **p. 33.**
Supers et M.F. (**Superheterodynes** and Medium Frequency).—J. Vivié, **p. 34.**
The Impedance Adjusting **Transformer.**—C. T. Burke, **p. 518.**
Characteristics of Output **Transformers.**—J. M. Thomson, **p. 640.**
Note on Radio Frequency **Transformer** Theory.—Diamond and Stowell, **p. 685.**
The **Tuned-grid,** Tuned-plate, Self-oscillating Vacuum-tube Circuit.—J. W. Wright, **p. 639.**
Les Circuits à Deux Ondes et leurs Applications (**Two-wave** circuits and their applications).—L. Brillouin and E. Fromy, **p. 223.**
Die Selbsterregungsbedingungen bei Rückkopplungs-Röhrensendern für sehr kurze Wellen (Conditions for self-excitation in reactively-coupled valve transmitters for **very short** waves).—W. Pfitzer, **p. 685.**
Theory of the Valve Maintained **Vibrating System.**—S. Jimbo, **p. 32.**
Determination of the **Voltage-amplification**-coefficient of H.F. Amplifiers with Resistances.—Witorsky and Konaschinisky, **p. 398.**
Voltage Detection Coefficient.—E. L. Chaffee, **p. 33.**
The Theory of **Wave Filters** containing a Finite Number of Sections—H. A. Wheeler, **p. 518.**
Kettenleiter, (1) Drossel-und Kondensatorketten, (2) Siebketten (**Wave-filters,** (1) Choking-coil-and condenser filters, (2) Waveband filters).—H. Bock, **p. 398.**
Uber das Verhalten Symmetrischer, Verlustfreier Kettenleiter zwischen ohmschen Widerständen (The behaviour of symmetrical, loss-free **Wave-filters** between ohmic Resistances).—R. Feldtkeller, **p. 398.**

TRANSMISSION.

Zusammengesetzte Rahmenantennen (Combined Frame **Aerials**).—Turlyghin and Ponomareff, **p. 641.**

Die Elektrischen Eigenschaften der Rundfunksender-Vorverstärker im Hinblick auf ihre akustischen Qualitäten (The electrical properties of broadcast transmitter preliminary **amplifiers** with a view to their acoustical qualities).—H. Rukop, **p. 343.**

Note sur le Choix Préliminaire des Constantes Electriques d'une Antenne Pseudosymétrique (Note on the preliminary choice of the electric constants of a pseudosymmetrical **antenna.**—(M. Waserman, **p. 224.**

Complex Transmitting **Antennæ.**—Turlygin and Ponomarev, **p. 518.**

Generalised Theory of **Antennæ.**—R. M. Wilmotte, **p. 224.**

Calcul des Constantes Electriques et Mécaniques des Antennes Pseudosymétriques avec Application aux Antennes genre FL (Calculation of the electrical and mechanical constants of pseudosymmetrical **antennæ,** with application to antennæ of the FL type).—M. Stern, **p. 35.**

Les Antennes d'Emission (Transmitting **antennæ**).—M. A. Cremailh, **p.34.**

Compensation des Courants Induits entre Antennes Emettrices Voisines (Compensating the currents induced between neighbouring transmitting **antennæ**).—H. Chireix and R. Villem, **p. 286.**

Über die Zieherscheinung beim Lichtbogen-generator (On oscillation hysteresis phenomena in the **arc** generator).—H. Poleck, **p. 165.**

Bemerkungen zu der Arbeit von Horst Winkler " Zieherscheinungen beim Lichtbogensender " (Remarks on Horst Winkler's paper, " Oscillation hysteresis phenomena in the case of **arc** transmitters ").—W. Burstyn, **p. 224.**

La Théorie du Rayonnement de la Beam Antenne (The Theory of the Radiation from a **Beam** Aerial).—G. F. d'Ailly, **p. 463.**

On the Wireless **Beam** of Short Electric Waves (VIII).—S. Uda, **p. 103.**

On the Wireless **Beam** of Short Electric Waves (IX).—S. Uda, **p. 103.**

On the Wireless **Beam** of Short Electric Waves: High Angle Radiation of Horizontally Polarised Waves.—S. Uda, **p. 580.**

Transmitting Aerials for **Beam** Stations.—S. I. Turlyghin, **p. 399.**

General Considerations of the Directivity of **Beam** Systems.—R. M. Wilmotte, **p. 641.**

A Theoretical Investigation of the Phase Relations in **Beam** Systems.—Wilmotte and McPetrie, **p. 641.**

" **Beam** " Wireless Telegraphy.—N. Wells, **p. 463.**

Allocation of European **Broadcast** Wavelengths (Some New Points of View).—S. Lemoine, **p. 519.**

Recent Developments in Low Power and **Broadcasting** Sets.—I. F. Byrnes, **p. 463.**

Recent Development in Low Power and **Broadcast** Transmitters. **p. 581.**

Die Rundfunksender der Welt (The World's **Broadcasting** Stations). **p. 463.**

The Design of **Choke Coils** and Transformers which carry a Direct Current.—G. W. O. Howe, **p. 165.**

Neuere Anwendungen der Modulations-drosseln (Recent applications of modulating **chokes**).—L. Pungs and F. Gerth, **p. 165.**

The Design of Variable **Condensers** for High Voltage Operations.—B. E. Smith, **p. 464.**

La Direction des Ondes Radioélectriques, Radio-Communications par Ondes Courtes Projetées (The **direction** of radio-electric waves. Radio communication by directed short waves).—L. Bouthillon, **p. 580.**

The **Distribution** of Current in a Transmitting Antenna.—R. M. Wilmotte, **p. 463.**

Short-wave Aerial Systems: An Elementary Theory of the Transmission of High-Frequency Energy Along the **Feeders.**—E. Green, **p. 463.**

Note au sujet des Ondes de quelques Mètres (Note on Waves of a **few Metres** Length).—R. Mesny, **p. 687.**

The Nature of the **Field** in the Neighbourhood of an Antenna.—R. M. Wilmotte, **p. 641.**

Über die Felder der Wechselstromleitung mit Erde und der Horizontalantenne (On the **fields** of alternating current wires with earth and the horizontal antenna).—F. Pollaczek, **p. 165.**

Über die von einem Abreissenden modulierten ungedämpften Sender gelieferte Schwingungsform (On the **form** of oscillation yielded by an interrupted modulated continuous wave transmitter).—F. A. Fischer, **p. 224.**

Frequenzdurchgang bei Modulierten fremdgesteuerten Sendern mit mehreren gekoppelten Schwingkreisen (Frequenzkurven) (**Frequency** variation in modulated externally controlled transmitters with several coupled oscillatory circuits (frequency curves).—P. v. Handel, **p. 342.**

Über die Günstigste Belastung des Hoch-frequenz-generators (The Optimum Loading of the H.F. **Generator**).—Y. Watanabe, **p. 580.**

Vacuum Tubes as Oscillation **Generators.**—D. C. Prince and F. B. Vogdes, **p. 343.**

Vacuum Tubes as Oscillation **Generators.**—D. C. Prince and F. B. Vogdes, **p. 686.**

The Radiation Resistance and Energy Capacity of **Half-wave** Aerials.—E. Green, **p. 165.**

I.E.E. Wireless Section: Chairman's Address.—A. G. Lee, **p. 286.**

Considerations affecting the **Licensing** of High-frequency Stations.—S. C. Hooper, **p. 686.**

Über den Verlustwiderstand bei Leitung von Hochfrequentem Wechselstrom durch Erde (On the resistance **loss** when alternating current of high frequency is conducted through the earth.)—R. Mayer, **p. 342.**

Production of Intense Extra-short Electromagnetic Waves by " Split-anode **Magnetron.**"—K. Okabe, **p. 399.**

Study of **Modulation** in Wireless Telephony.—S. Chiba, **p. 343.**

Polar Diagrams Due to Plane Aerial Reflector Systems.—T. Walmsley, **p. 641.**

The **Power** in a Modulated Oscillation.—E. Howard Robinson, **p. 343.**

Strahlungsdichte und Empfangsfläche (**Radiation** density and receiving Surface).—M. Dieckmann, **p. 286.**

Étude d'un Générateur à Ondes Courtes (Study of a **Short-wave** Generator).—F. Flaud, **p. 464.**

50 Watt aus 220 Volt! Ein Einfacher und Leistungsfähiger Kurzwellensender (A simple and efficient **short-wave** transmitter).—W. Nestel, **p. 399.**

Some Experiments with Side-Band Telephony on **Short** Wavelengths.—E. Howard Robinson, **p. 35.**

Technical Considerations involved in the Allocation of **Short** Waves (frequencies between 1.5 and 30 megacycles).—L. Espenschied, **p. 518.**

The New York-London **Telephone** Circuit.—S. B. Wright and H. C. Silent, **p. 34.**

Ein Röhrengenerator zur Erzeugung von modulierter Hochfrequenz für Laboratoriumszwecke (A valve **transmitter** for the production of modulated high frequency for laboratory purposes).—F. Gabriel, **p. 34.**

Ultrakurze Elektrische Wellen (**Ultra-short** electric waves).—A. Esau, **p. 640.**

Theorie der Erzeugung von sehr Kurzen Elektromagnetischen wellen Mittels Elektronenröhren (Theory of valve-production of **ultra-short** E. M. Waves).—J. Sahánek, **p. 640.**

Beam Transmission of **Ultra-short** Waves.—H. Yagi, **p. 519.**

Telephonie auf Extrem Kurzen Wellen (Telephony on **Ultra-short** waves).—H. E. Hollmann, **p. 580.**

Die Erzeugung Sehr Kurzer Elektrischer Wellen mit Wechselspannung nach der Methode von Barkhausen und Kurz (The production of **ultra-short** waves by the B-K method but with A.C. voltage).—W. Wechsung, **p. 580.**

Die Erzeugung sehr kurze Elektrischer Wellen mit Wechselspannung . . . (The Productions of **very short** waves with A.C. voltage . . .).—W. Wechsung, **p. 641.**

Röhrengenerator grosser Leistung für sehr kurze elektrische Wellen (A Power Valve Generator for **very Short** Waves).—H. Wechsung, **p. 518.**

Ein Röhrenoszillator für sehr kurze Ungedämpfte Wellen (A valve oscillator for **very short** undamped waves).—H. E. Hollmann, **p. 641.**

RECEPTION.

A.C. Tubes Versus Series Filament Operation.—W. P. Lear, **p. 464.**

The Use of **Alternating Current** for Heating Valve Filaments.—C. W. Oatley, **p. 520.**

Die Verwendung von Wechselstromröhren (The use of **alternating current** valves).—R. Wigand, **p. 399.**

American Sets of To-day: Progress in Radio Receiver Design during the Last Year (Illustrated), **p. 464.**

Eindversterkerproblemen (Problems of the final stage of **amplification**).—B. D. H. Tellegen, **pp. 399** and **519.**

On the Theory of Power **Amplification.**—M. von Ardenne, **p. 286.**

L'Amplification à Haute Fréquence par Transformateur à Secondaire Accordé (High-frequency **amplification** by transformer with tuned secondary).—G H. d'Ailly, **p. 400.**

The Final or Power Stage of **Amplifiers.**—M. v. Ardenne, **p. 642.**

Anode Bend or Grid Rectification?—A. P. Castellain, **p. 225.**

Anode and Grid Rectification.—A. L. Sowerby, **p. 287.**

Notice sur le Régulateur **Anti-fading, p. 519.**

The Reduction of **Atmospheric** Disturbances.—J. R. Carson, **p. 581.**

Direct Coupled Detector and Amplifiers with **Automatic** Grid Bias.—E. H. Loftus and S. Y. White, **p. 286.**

Mauvaise Réception en Radiophonie (Faulty **broadcast** reception).—R. Braillard, **p. 35.**

Cascade H.F. Amplifiers (A Super-sensitive Receiver " by instalments ").—H. F. Smith, **p. 399.**

A Plea for **Choke-Coupling.**—A. L. Sowerby, **p. 35.**

What is the Correct Characteristic for a Variable **Condenser**?—K. E. Edgeworth, **p. 225.**

Zusammenfassender Bericht: Der Kristalldetektor (The **crystal** detector: survey of the subject).—A. Schleede and H. Buggish, **p. 225.**

Über den Schwingkristall (On the oscillating **crystal.**)—K. Sixtus, **p. 287.**

The Apparent **Demodulation** of a Weak Station by a Stronger One.—R. T. Beatty, **p. 464.**

A Novel Valve **Detector.**—H. J. Neill, **p. 165.**

A New Idea for a **Detector** Valve (Posthumous), **p. 642.**

Sur une Anomalie dans le Fonctionnement des Détecteurs à Contact et sur ses Conséquences (On an anomaly in the operation of contact **detectors** and its consequences).—J. Groszkowski, **p. 225.**
Sur une Vérification de la Théorie des Détecteurs et Redresseurs à Contact (On a verification of the theory of contact **detectors** and rectifiers).—M. Dubar, **p. 102.**
The Dangers of **Detuning.**—A.L.M.S., **p. 165.**
Die Fernbedienung von Funksempfangsanlagen (Attending to radio receiving installations from a **distance**).—A. Ristow, **p. 343.**
Working on **8 Metres.**—C. D. Abbott, **p. 286.**
Endverstärkerprobleme.—B. D. H. Tellegen, **pp. 399** and **519.**
Europa-empfang im lautsprecher mit 2 bis 3 Röhren (Reception of **European** stations on loud-speaker with 2 to 3 valves).—C. Riedel, **p. 400.**
Drei Einröhren-Experimentier-Empfänger (Three One-Valve **Experimental** Receivers).—Günther and Schreiber, **p. 464.**
Fading and the Detector: Advantages of Leaky Grid Detection in Minimising Effects of Fading, **p. 687.**
Die Verwendung von Siebkreisen (The Use of **Filter** Circuits).—W. Nestel, **p. 464.**
Die Anwendung der Rahmenantenne (The use of **frame-aerials**).—E. Schwandt, **p. 399.**
Sur les Contacts Imparfaits (On **imperfect contacts**).—H. Pélabon, **p. 35.**
The **Indirectly Heated** Cathode Receiver.—A. P. Castellain, **p. 287.**
Locating and Correcting Propagated Radio **Interference.**—C. Evans, **p. 165.**
Tracing Radio **Interference.**—J. Hanly, **p. 165.**
The **Kilo-mag Four**: A Screened Grid Set with a Thousand-fold H.F. Amplification.—H. F. Smith, **p. 687.**
The **Last Stage, p. 102.**
Spannungsbegrenzer für Verstärker (Voltage **Limitation** for Amplifiers).—O. Kappelmayer, **p. 581.**
Loose Coupling (Some notes on two-circuit receivers).—"Radiophare," **p. 520.**
Low-frequency Oscillation.—U.I.G.P., **p. 165.**
Ein Netzanschlussempfänger für 220-volt Gleichstrom (A "**mains-fed**" receiver for 220 volts D.C. supply).—A. Leunig, **p. 399.**
Valve Current from A.C. **Mains.**—J. K. Jennings, **p. 165.**
Über den Netzanschluss von Widerstandverstärkern (**Mains** Supply for Resistance Amplifiers).—H. Kröncke, **p. 464.**
Mains Supply for Valve Receivers, **p. 581.**
Further Notes on the "**Megavox Three.**"—N. W. McLachlan, **p. 687.**
Le Phénomène de Miller dans L'Amplification Haute Fréquence (The "**Miller**" effect in high frequency amplification).—G. H. d'Ailly, **p. 519.**
Fernempfang mit Mehrfachröhren (Distant reception with **multiple-valves**).—R. Neuroth, **p. 581.**
Modern **Naval** Receivers (Long-Range Sets with Screened Grid H.F. Amplifiers), **p. 464.**
New Apparatus, **p. 399.**
The Causes and Prevention of Actual and Incipient L.F. **Oscillation.**—W. I. G. Page, **p. 343.**
A Radio-receiving **Oscillator** for Receiver Investigations.—G. Rodwin and T. Smith, **p. 224.**
Wireless at the **Paris** Fair (Some Interesting Exhibits Described), **p. 464.**
The **Pentode.**—W. I. G. Page, **p. 520.**
The Output Stage and the **Pentode.**—N. W. McLachlan, **p. 520.**
Ein Reise-empfänger mit einer Vierfachröhre (A **portable** receiver with one four-anode valve).—N. Werner, **p. 400.**
The **Power Supply** of Wireless Sets.—G. F. J., **p. 102.**
Progress in Radio Receiving during 1927.—A. N. Goldsmith, **p. 287.**
A New Method of **Push-pull** (Advantages to be gained by Employing Tapped Loud-speaker Windings).—L. E. T. Branch, **p. 399.**
The Theory of "**Push-pull.**"—N. W. McLachlan, **p. 464.**
Amplification and High **Quality** (Permissible Gain per Stage for Good Reproduction).—N. W. McLachlan, **p. 399.**
Quality and the Anode Rectifier.—A. L. Sowerby, **p. 165.**
Good **Quality** in H.F. Amplifiers.—C. Inglis, **p. 225.**
Sur la Qualité de la Reproduction Radio-phonique (The **quality** of radiophonic reproduction).—P. David, **p. 581.**
Quantitative Determination of Radio-receiver Performance, **p. 102.**
Smooth **Reaction** Control.—A. P. Castellain, **p. 287.**
Compromise in **Receiver** Design (Part 5. The H.F. Amplifier. How the Tuned Circuits Affect Quality), **p. 581.**
A High-efficiency **Receiver** for a Horn-type Loud-speaker of Large Power Capacity.—E. C. Wente and A. L. Thuras, **p. 224.**
A New **Receiver**: The Design of a Screened Grid and Pentode Three.—N. W. McLachlan, **p. 642.**
Un 4 Valvole di Uso Generale (A 4-valve general purpose **receiver**).—U. Guerra, **p. 225.**
High-Note Loss in **Resistance** Amplifiers.—A. L. Sowerby, **p. 287.**
A New Method of Using **Resistance** Amplification with Screened Grid Valves.—J. J. Dowling, **p. 165.**
Calculations for **Resistance** Amplifiers.—A. L. M. Sowerby, **p. 287.**
Retro-action in Amplifiers.—H. A. Thomas, **p. 343.**
Weiteres über die Schirmgitterröhre (More about the **Screened-grid Valve**).—H. Kröncke, **p. 399.**
Ein Empfänger mit schirmgitterröhre (A receiver with **screened-grid** valve).—O. A. Klotz, **p. 399.**
Ein Fünfröhren-interflex-empfänger mit Abstimmbarer Abschirmung (A 5-valve-interflex-receiver with adjustable **screening**).—H. Günther, **p. 400.**
The Problem of **Selectivity.**—A. Castellain, **p. 35.**
Ein Einfacher Kurzwellen-empfänger mit Zweifachröhre (A simple **short-wave** receiver with double-anode valve).—W. Nestel, **p. 400.**
Bau und Betrieb eines Kurzwellenempfängers mit einer N.F.-Dreifächröhre (Construction and Use of a **Short-wave** Receiver with One L.F. Triple Valve).—M. v. Ardenne, **p. 641.**
Untersuchungen an einen Empfangsgerät fur kurze Wellen (Investigation of a receiving instrument for **short** waves).—O. Cords, **p. 286.**
Rectifiers and **Smoothing** Circuits.—F. Record and I. H. Holmes, **p. 102.**
System for Combating Effects of **Static.**—E. A. Tubbs, **p. 520.**
Harmoniques et **Super-réaction.**—L. La Porte, **p. 400.**
Les "Super-réactions" (**Super-regeneration**).—P. David, **p. 519.**
Un **Super-Valise** (A Super- "suit-case" -receiver).—G. Chaillon, **p. 399.**
Switch-over Three.—H. F. Smith, **p. 520.**
Some Correlations of Radio Reception with Atmospheric **Temperature** and Pressure.—G. W. Pickard, **p. 519.**
Wert und Wirksamkeit des Tonveredlers (The value and efficiency of the "**tone-improver**").—E. Schwandt, with reply by H. Kröncke, **p. 399.**
Der Betrieb Eines Hochleistungs-tropadyn-empfängers (The working of a high-efficiency **Tropadyne** receiver).—E. Schwandt, **p. 400.**
Tuned Radio-Frequency Amplifiers.—R. S. Glasgow, **p. 464.**
Two-range Four.—F. H. Haynes, **p. 642.**
Über unverzerrte Leistungsabgabe durch Elektronenröhren (On **undistorted** reproduction with valves).—A. Forstmann, **p. 343.**
Valve Crystal Receiver: A Non-radiating Super-sensitive One-valve Loud-speaker Set.—P. W. Willans, **p. 400.**
Volume Control, **p. 287.**
Automatic **Volume** Control, **p. 35.**
Automatic **Volume** Control for Radio Receiving Sets.—H. A. Wheeler, **p. 165.**
Radio Receiver **Volume** Control.—A. B. Whittaker, **p. 687.**
A Note on **Volume** Control, **p. 102.**
Acoustic **Wave Filters** and Audio-frequency Selectivity.—R. B. Bourne, **p. 641.**

VALVES AND THERMIONICS.

The Application of **Alignment Charts** to Valve Characteristics.—M. Reed, **p. 642.**
Über den Einfluss Hoher Ohmscher Anodenwiderstände auf den Gitterwiderstand von Verstärkerröhren (The influence of high ohmic **Anode-resistances** on the Grid-resistance of Amplifier-valves).—E. Döring, **p. 400.**
Über die Kompensation der Schädlichen Kapazitäten und Ihrer Rückwirkungen bei Elektronenröhren (The compensation for undesired **capacities** and their effects in valves).—V. Ardenne and W. Stoff, **p. 402.**
Über die Kompensation der Schädlichen Kapazitaten . . . (The Compensation for undesired **capacities** . . .).—Ardenne and Stoff, **p. 466.**
The New **Cosmos** A.C. Valve, **p. 36.**
The **Cossor** Screened Valve, **p. 103.**
Die Stromverteilung in Dreielektrodenröhren und Ihre Bedeutung für die Messung de Voltaspannungen (**Current-distribution** in three-electrode Valves and its importance for the measurement of Contact-potentials).—H. Lange, **p. 400.**
Die Stromverteilung in Dreielectrodenröhren . . . (**Current distribution** in three-electrode valves . . .).—H. Lange, **p. 466.**
Die Stromverteilung in Dreielektrodenröhren . . .—H. Lange, **p. 520.**
A propos de la Recherche de la Démodulation Parfaite (The search after perfect **demodulation**).—G. E. Petit, **p. 401.**
Une Suggestion Nouvelle pour Augmenter l'Efficacité de la Détection (A New Suggestion for increasing the Efficiency of **Detection**).—J. Marcot, **p. 582.**
La Détection par Lampe (**Detection** by Valve).—P. David, **p.642.**
Electron Emission in Intense Electric Fields.—R. H. Fowler and L. Nordheim, **p. 400.**
Über den Mechanismus von Elektronen Schwingungen (The Mechanism of **Electron-oscillations**).—H. E. Hollmann, **p. 582.**
The Restored **Electron Theory** of Metals and Thermionic Formulæ.—R. H. Fowler, **p. 226.**
Einige Überlegungen zur physikalischen Bedeutung der Glühelektronen-Emission (Some considerations on the physical significance of incandescent electron **emission**).—A. v. Hippel, **p. 344.**
Relations of **Field-Currents** to Thermionic-Currents.—R. A. Millikan and C. C. Lauritsen, **p. 344.**
On Electrical **Fields** near Metallic Surfaces.—J. Becker and D. Mueller, **p. 225.**
On Electrical **Fields** near Metallic Surfaces.—J. Becker and D. Mueller, **p. 288.**
The Valve **Filament** at Constant Voltage.—E. H. Banner, **p. 36.**

Graphs for the Design of Bright-emitting Tungsten **Filaments.**—N. Kato, **p. 688.**

Some Characteristics and Applications of **Four-electrode** Tubes.—J. C. Warner, **p. 345.**

Applications Nouvelles des Lampes à Quatre Electrodes (New applications of **four-electrode** valves).—B. Decaux, **p. 343.**

Characteristic Curves of the **Four-electrode** Valve.—N. R. Hall, **p. 287.**

Detection with the **Four-electrode** Valve.—J. R. Nelson, **p. 521.**

Four-element Tube Characteristics as Affecting Efficiency.—D. C. Prince, **p. 521.**

The **Frenotron** Valve—A Vienna Novelty, **p. 287.**

Frequency Variations of the Triode Oscillator.—K. E. Edgeworth, **p. 287.**

Frequency Variations of the Triode Oscillator.—D. F. Martyn, **p. 520.**

Elektronenströme und Raumladung in dichten Gasen (Electron-currents and Space-charge in dense **Gases**).—F. Skaupy and W. Daudt, **p. 687.**

Oscillations in Ionised **Gases.**—I. Langmuir, **p. 687.**

Detection by **Grid** Rectification with the High-vacuum Triode.—S. Ballantine, **p. 465.**

Some Past Developments and Future Possibilities in very **High Voltage** Vacuum Tubes.—W. D. Coolidge, **p. 344.**

The Effect of **Initial Velocity** of Electrons upon the Anode Current of a Vacuum Tube.—N. Kato, **p. 465.**

Ionen und Elektronen in der Vakuumglühlampe (**Ions and electrons** in incandescent lamps).—P. Selényi, **p. 582.**

On the Cause of the **Loss** of Thermionic Activity of Thoriated Tungsten Filaments under certain Voltage Conditions.—A. C. Davies and R. N. Moss, **p. 401.**

Eine Gross-verstarkerröhre mit Quecksilberdampf (A high-power **Mercury Vapour** Valve).—E. Lübcke, **p. 582.**

New Uses for Valves.—A. Dinsdale, **p. 36.**

Détermination de la Condition d'Entretien et de la Période d'Oscillation d'un Oscillateur à Triode (Determination of the condition for the maintenance of **oscillation** and of the period of the oscillation, in a three-electrode valve oscillator).—L. Abélès, **p. 401.**

Les Différentes Méthodes de Détermination de la Condition d'Entretien des Oscillations dans les Émetteurs à Lampes (The different methods of determining the conditions for the maintenance of **oscillations** in valve transmitters.—F. Bedeau), **p.581.**

Sur un Nouveau Mode d'Entretien d'Oscillations dans les Lampes Triodes (A new manner of producing **oscillations** in three-electrode valves).—E. Pierret, **p. 402.**

Use of an **Oscillograph** for Recording Vacuum-tube Characteristics.—W. A. Schneider, **p. 465.**

Über den Emissionsmechanismus von Oxydkathoden (On the mechanism of emission from **oxide** cathodes).—W. Espe, **p. 166.**

Die technische Herstellung von Oxydkathoden (Industrial production of **oxide** cathodes).—W. Statz, **p. 225.**

Die Austrittsarbeit von Elektronen aus Erdalkalioxydkathoden (The work of emission of electrons from cathodes with alkaline-earth **oxides**).—W. Espe, **p. 166.**

Photo-electric Emission, Thermionic Emission and Peltier Effect.—E. H. Hall, **p. 226.**

The Photo-electric and Thermionic Work Functions of Outgassed **Platinum.**—L. Du Bridge, **p. 226.**

Platinum Alloys in Thermionic Valves, **p. 465.**

On the Emission of **Positive** Electricity from Hot Tungsten in Mullard Radio Valves.—P. Kumar Mitra, **p. 166.**

The Effects produced by **Positive Ion** Bombardment of Solids: Metallic Ions.—M. L. Oliphant, **p. 582.**

Investigation of the Thermionic Properties of the **Rare-earth** Elements.—E. Schumacher and J. Harris, **p. 166.**

New Valve **Rectifier.**—A. Gehrts, **p. 225.**

Kleingleichrichter für Rundfunkzwecke (Small **rectifiers** for broadcast purposes).—M. Bareiss, **p. 225.**

Rejuvenating Rectifying Valves, **p. 344.**

The Effect of **Residual Gas** in a Valve.—A. P. Castellain, **p. 344.**

Schrot-effect in High Frequency Circuits.—S. Ballantine, **p. 582.**

The **Screen-grid** Tube.—N. H. Williams, **p. 521.**

The Approximate **Theory** of the **Screen-grid** Valve.—B. C. Brain, **p. 287.**

Die **Abgeschirmten** Röhren (**Screen-grid** Valves).—M. v. Ardenne, **p. 521.**

Screened-grid Valve as a Detector: Some Interesting Data based on Actual Measurement.—A. P. Castellain, **p. 687.**

Screened-grid Valves: Informal Discussion at I.E.E. Wireless Section, **p. 465.**

Secondary Electrons from Cobalt.—M. N. Davis, **p. 521.**

L'Influence des Émissions Secondaires des Métaux sur le Fonctionnement des Lampes à Trois Électrodes (The influence of **secondary emission** from metals on the working of three-electrode valves).—H. Le Boiteux, **p. 465.**

Short Undamped Electric Waves.—K. Kohl, **p. 464.**

Space-charge Effects.—E. W. B. Gill, **p. 401.**

The Action of **Strong Electric Fields** on the Current from a Thermionic Cathode.—de Bruyne, **p. 642.**

Über die Vergrösserung des Sattigungsstromes von Glühkathoden durch Starke Elektrische Felder (The Increase of Saturation Current through **Strong Electric Fields**).—W. S. Pforte, **p. 582.**

Zur Theorie der Raumladegitterrohren (The Theory of the **Space Charge** Grid Valve) Part I.—F. Below, **p. 642.**

Thermal Agitation of Electricity in Conductors.—J. B. Johnson; and Thermal Agitation of Electric Charge in Conductors.—H. Nyquist, **p. 581.**

Einige Überlegungen zur Physikalischen Bedeutung der Glühelektronenemission (Some considerations as to the physical meaning of **thermionic emission**).—v. Hippel, **p. 465.**

Thermionic Emission and the "Universal Constant" *A*.—E. H. Hall, **p. 226.**

An Empirical **Thermionic** Emission Formula.—V. I. Volynkin, **p. 520.**

Theory of the Internal Action of **Thermionic** Systems at Moderately High Frequencies.—Part I.—W. E. Benham, **p. 288.**

Les Lampes à Trois Grilles et leurs Montages (Valves with **three grids** and their circuits).—M. Chauvierre, **p. 287.**

Empirical Formulæ for Dependence of **Tungsten** Resistance on Temperature.—N. D. Morgulis, **p. 688.**

A Note on the Thermionic Work Function of **Tungsten.**—C. Davisson and L. Germer, **p. 36.**

The Overshooting of the Temperature of a **Tungsten** Filament.—L. Bockstahler, **p. 225.**

A Comparison of the Thermionic and Photo-electric Work Functions for Clean **Tungsten.**—A. H. Warner, **p. 226.**

Critical Primary Velocities in the Secondary Electron Emission of **Tungsten.**—H. Krefft, **p. 226.**

Étude Expérimentale et Théorique des Lampes à deux Électrodes (Experimental and theoretical study of **two-electrode** valves).—Y. Doucet, **p. 464.**

Über die Gleichzeitige Erregung Zweier Schwingungen in einer Dreielektrodenröhre (The Simultaneous Excitation of **Two Oscillations** in One Three-electrode Valve).—Hans Mögel, **p. 401.**

Are there too many **Types** of Valves?—E. V. Appleton, **p. 287.**

Valve Classification.—A. L. M.-S., **p. 288.**

Development of a New Power Amplifier **Valve.**—C. R. Hanna, L. Sutherlin, and C. B. Upp, **p. 344.**

Die Entwicklung im Elektronenröhrenbau (Development in **valve** construction).—H. Simon, **p. 225.**

Recherches et Essais sur les Lampes de T.S.F. (Research and Tests on Wireless **Valves**).—A. Kiriloff, **p. 688.**

Über die Erregung sehr schneller Elektrischer Schwingungen in der Drei-Elektrodenröhre (The Excitation of **very Rapid** Oscillations in the 3-electrode Valve).—O. Pfetscher, **p. 521.**

Very Short Undamped Waves in a Receiving Valve.—D. Rozanskij, **p. 520.**

Sur la Réalisation et le Fonctionnement d'un Nouvel Oscillateur à Ondes Très Courtes (The construction and method of working of a new oscillator for **very short** waves).—E. Pierret, **p. 465.**

DIRECTIONAL WIRELESS.

L'Excitation d'une Antenne en Fonction de la Direction du Champ Électromagnétique (The Excitation of an **Aerial** as a Function of the Direction of the E.M. field).—G. Hack, **p. 642.**

Le Radiocompas et la Navigation Aérienne (The radio compass and **aerial navigation**).—P. Franck, **p. 345.**

Aircraft Radio and Navigation.—R. Gunn, **p. 521.**

Development of Radio Aids to **Air Navigation.**—Dellinger and Pratt, **p. 582.**

Radio Communication Development in **America, p. 288.**

Directional Properties of Transmitting and Receiving **Antenna.**—Clapp and Chinn, **p. 466.**

Rotating-**Beacon** Radio Transmitters, **p. 226.**

The Equi-signal System of Radio **Beacon** for Aircraft to Set Courses by Projecting Equi-signal Zones of Interlocked Signals, **p. 466.**

Directional Wireless and Marine Navigation: the Rotating-Loop **Beacon.**—R. L. Smith-Rose, **p. 402.**

Some Experiments of the Application of the Rotating-**Beacon** Transmitter to Marine Navigation.—R. L. Smith-Rose and S. R. Chapman, **p. 288.**

Airplane Radio-**Beacon** Variations Overcome, **p. 521.**

A Theoretical Discussion of Various Possible Aerial Arrangements for Rotating-**Beacon** Transmitters.—R. L. Smith-Rose, **p. 288.**

Apparent Night Variations with Crossed-coil Radio **Beacons.**—H. Pratt, **p. 466.**

Radio **Beacons** for Transpacific Flights.—C. C. Shangraw, **p. 688.**

Construction rapide, sur la carte, des lignes de relèvements constants pour utiliser les relèvements radiogoniométriques pris du bord (Quick construction on the **chart** of "lines of constant bearing," to utilise the D.F. bearings taken on board ship).—D. Gernez, **p. 402.**

Experiences in Radio **Compass** Calibration.—F. A. Kolster, **p. 688.**

Sur un Nouveau Dispositif d'Alignment par Emissions Hertziennes (On a new method of **course-setting** by wireless).—J. Aicardi, **p. 288.**

Note on a Special **Dial** for Time-pieces to be used with Rotating Wireless or other Beacons.—R. L. Smith-Rose, **p. 345.**

Über die von Leitergebilden in der Umgebung eines Funkpeilers Rückgestrahlten Störfelder und die Verfahren zu Ihrer Kompensierung (The **error-producing** field re-radiated by a conducting structure in the neighbourhood of a direction-finder, and its compensation).—F. A. Fischer, **p. 522.**

Radio Direction-finder : Part I.—The Theory of the **Frame Aerial** ; Avoiding Electrostatic **Pick-up**.—R. L. Smith-Rose, **p. 582.**

Sur un Procédé de Visée Radioélectrique applicable à la Géodésie (On a method of radio direction-finding applicable to **geodesy**).—P. Schwartz, **p. 288.**

Directional Radiation with **Horizontal** Antennas.—A. Meissner, **p. 36.**

Die Vergrösserung des Empfangsbereiches bei Doppelrahmen und Doppelcardioidenanordnungen durch Goniometer. (**Increasing** the range of reception with double frames and cardiode-arrangements by means of goniometers).—A. Esau, **p. 226.**

Directional Wireless as an Aid to **Navigation**.—R. L. Smith-Rose, **p. 36.**

Oscillographic Observations on the Direction of Propagation and fading of Short Waves.—H. T. Friis, **p. 466.**

Le Chemin du Rayon Électromagnétique (The **Path** of the electromagnetic Ray).—de la Forge, **p. 642.**

Rotating-Loop Radio Transmitters, and their Application to Direction-Finding and Navigation.—T. H. Gill and N. F. Hecht, **p. 288.**

Kurzwellenpeilversuche mit Rahmen und Hilfsantenne auf grössere Entfernungen über See (Experiments on **short-wave** direction-finding, with frame and auxiliary antenna, over greater distances, over sea).—F. A. Fischer, **p. 226.**

Untersuchungen über die Peilbarkeit kurzer Wellen bei Tag und Nacht (Experiments on the possibility of taking bearings on **short waves** by day and night).—F. Michelssen, **p. 226.**

MEASUREMENTS AND STANDARDS.

Limits of **Accuracy** in Physical Measurements.—A. E. Ruark, **p. 688**

Über Neuere Akustische und Insbesondere Elektroakustische Arbeiten (Latest Work on **Acoustics** and in particular Electro-acoustics.)—F. Trendelenburg, **p. 688.**

Über Neuere Akustische und Insbesondere Elektroakustische Arbeiten (Latest Work on **Acoustics** and in particular Electro-acoustics).—F. Trendelenburg, **p. 584.**

On the Use of the Electromagnetic Receiver in **Acoustical** Measurements.—T. S. Littler, **p. 37.**

A Note on Methods of Rapidly **Adjusting** a Radio-frequency Oscillator in Small Steps of Frequency.—J. K. Clapp, **p. 644.**

The Equivalent Inductance and Capacity of an **Aerial**.—(Editorial), **p. 466.**

Eine Einfache Methode zur Messung der Eigenwellenlänge von Antennen (A Simple Method of Measuring the Natural Wave-length of an **Aerial**).—H. Bruun, **p. 583.**

Nagra Teoretiska Synpunkter pa Smärre Mottagnungsantenner (Some theoretical points on small receiving **aerials**).—E. T. Glas, **p. 643.**

Leistungs- und Strahlungsmessungen an Flugzeug- und Bodenstationen (Power and Radiation Measurements in **Aeroplane** and Land Stations).—Eisner, Fassbender and Kurlbaum, **p. 467.**

Leistungs- und Strahlungs-Messungen an Flugzeug- und Bodenstationen (Power- and radiation-measurements in **aeroplane**- and land-stations).—Eisner, Fassbender and Kurlbaum, **p. 403.**

Geräuschmessungen in Flugzeugen (Noise Measurements in **Aircraft**).—Fassbender and Krüger, **p. 583.**

A New **Ammeter** for Measuring very High Frequency Currents, **p. 467.**

The Design of Non-contact Thermo-junction **Ammeters**.—Colebrook and Wilmotte, **p. 645.**

A New Method for the Calibration of **Ammeters** at Radio Frequencies.—H. C. Hazel, **p. 166.**

A Triode **Amplifier** for Small Direct Currents.—A. Marcus, **p. 227.**

Methods, Formulas, and Tables for the Calculation of **Antenna** Capacity.—F. W. Grover, **p. 346.**

Characteristics of Certain Broadcasting **Antennas** at the S. Schenectady Development Station.—H. M. O'Neill, **p. 583.**

Notes on Quartz Plates, Air Gap Effect, and **Audio-frequency** Generation.—A. Hund, **p. 643.**

A Graphical Method for Calculations by **Austin's** Formula.—N. P. Suvorov, **p. 584.**

Mesures et Essais Effectués avec l'Antenne Projecteur S.F.R.-C.M. (Measurements and Tests on the Soc. Fran. Radioelec. Chireix-Mesny **Beam** Aerial), **p. 689.**

A **Bridge** for the Measurement of Inductance and Capacity.—G. Zickner, **p. 346.**

A Direct-Capacity **Bridge** for Vacuum-Tube Measurements.—Lincoln Walsh, **p. 346.**

A Shielded **Bridge** for the Measurement of Inductance in Terms of Resistance and Capacity.—B. W. Bartlett, **p. 584.**

Laboratory Measurement of **Capacity, Power Factor, Dielectric Constant, Inductance and Resistance, by Use of the Series Resistance Bridge**.—C. L. Lyons, **p. 467.**

How **Broadcasting** Wavelengths are Checked.—R. Braillard and E. Divoire, **p. 227.**

Method of **Calibrating** a Low Frequency Valve Generator with a Single Frequency Standard Source.—T. S. Rangachari, **p. 689.**

valuation of the **Capacity** of Flat Condensers in the case of Unparallel Plates.—Florensky and Popoff, **p. 403.**

he Measurement of Small Variable **Capacities** at Radio-frequencies.—W. H. F. Griffiths, **p. 645.**

Measurement of Vacuum-tube **Capacities** by a Transformer Balance.—H. A. Wheeler, **p. 346.**

Dielektrische Messungen an Einem Cellonkondensator bei Mittleren Frequenzen und Niederspannung (Dielectric Measurements on a "**Cellon**" Condenser at Medium Frequencies and Low Voltages).—W. Hubmann, **p. 689.**

The Standardisation of Stationary Secondary **Cells** in the British Post Office.—H. C. Jones, **p. 688.**

Coil Calculations, **p. 346.**

Electrical Measurement of **Communication** Apparatus.—W. J. Shackleton and J. G. Ferguson, **p. 227.**

Condenser Shunt for Measurement of High-frequency Currents of Large Magnitude.—A. Nyman, **p. 227.**

The Demonstration of a New Precision Wavemeter **Condenser**.—W. H. F. Griffiths, **p. 346.**

Basic Measurements of the Effective Resistance of **Condensers** at Radio-frequencies.—D. W. Dye, **p. 644.**

The Accuracy and Calibration Permanence of Variable Air **Condensers** for Precision Wavemeters.—W. H. Griffiths, **p. 166.**

Notes on the Accuracy of Variable Air **Condensers** for Wavemeters.—W. H. Griffiths, **p. 37.**

On the Application of **Condensers** to the Measurement of Large Radio-frequency Currents.—P. R. Coursey, **p. 645.**

Study on the Natural Electrical Oscillations of **Conical** Coils.—I. Yamamoto, **p. 582.**

New Precision in **Cosmic** Ray Measurements, yielding Extension of Spectrum and Indications of Bands.—R. A. Millikan and G. H. Cameron, **p. 689.**

The **Dielectric Constant** of Air at Radio-frequencies.—Bryan and Sanders, **p. 644.**

Nouvelle Méthode pour la Mesure Absolue, en Haute Fréquence, des Constantes Diélectriques des Liquides (A new method for the absolute measurement of the **dielectric constant** of liquids, at high frequency).—R. Darbord, **p. 228.**

Eine Neue Methode zur Experimentellen Aufnahme der Richtkennlinie einer Antenne (A new method for the experimental plotting of the **directional**-characteristic-curve of an aerial).—F. A. Fischer, **p. 403.**

Dispersionsmessungen im Gebiete kurzer elektrischer Wellen (**Dispersion** measurements in the region of short electric waves).—W. Heim, **p. 228.**

Verfahren zur Ermittlung der wirksamen Höhe von Antennen und des Empfangs wertes einer Anlage unter Mitbenutzung des Biot-Savartschen Feldes in unmittelbarer Antennennähe (A method of ascertaining the **effective height** of Aerials and the receptive value of an installation by the aid of the Biot-Savart Field in the immediate neighbourhood of the aerial).—Max Dieckmann, **p. 402.**

The Power-factor and Capacity of the **Electrodes and Base** of Triode Valves with Special Reference to Their Use in Thermionic Voltmeters.—G. W. Sutton, **p. 103.**

A Simple Gold Leaf **Electrometer** for High-frequency Measurements.—Satyendranath Ray, **p. 645.**

A Quartz Fibre **Electrometer**.—D. R. Barber, **p. 643.**

Contact Potential in the Dolezalek **Electrometer** Connected Idiostatically.—L. F. Richardson, **p. 644.**

Mésures électrométriques de tres faibles différences de potentiel alternatives (**Electrometer** measurements of very small A.C. potential differences).—Gutton and Laville, **p. 689.**

Measurement of Radio **Field Intensity**.—V. I. Bashenoff, **p. 689.**

Die Physikalischen Grundlagen und die Technik der Feldstarkemessung in der Drahtlosen Telegraphie (The theory and practice of **Field Strength** Measurement in Wireless).—M. Bäumler, **p. 583.**

Geräte zur Messung von Empfangsfeldstärken in der drahtlosen Telegraphie und Telephonie (Instruments for measuring **field-strength** in wireless telegraphy and telephony).—G. Anders, **p. 166.**

Diagramme des Champs Electriques Mesurés à Meudon Pendant le Premier Semestre, 1927 (Graphs of the electric **fields** measured at Meudon during the first half of 1927), **p. 166.**

Sur les Forces Électromagnetiques S'Exerçant entre Conducteurs (The Electro-magnetic **Forces** Between Conductors).—W. F. Dunton, **p. 583.**

A **Frequency** Standard.—W. A. Marrison, **p. 688.**

Measurement of **Frequency**.—S. Jimbo, **p. 345.**

Precision Determination of **Frequency**.—J. Horton and W. Marrison, **p. 227.**

The (U.S.A.) Navy's Primary **Frequency** Standard.—Worrall and Owens, **p. 523.**

The Status of **Frequency** Standardisation.—J. H. Dellinger, **p. 522.**

A Precision Method for the Measurement of High **Frequencies**.—C. B. Aiken, **p. 227.**

A **Long-period Galvanometer**.—D. C. Gall, **p. 644.**

Graphical Computation.—M. H. Ashworth, **p. 468.**

A **Graphical** Construction for Resistance Amplifiers.—W. A. Barclay, **p. 645.**

The Use of the **Grid-Glow** Tube as an Electro-static Voltmeter.—T. Wilkins and F. Friend, **p. 228.**

Ground Resistance Testing.—W. B. Craigmile, **p. 523.**

A Mechanical **Harmonic Analyser** for Cathode Ray Oscillograms.—C. G. Wiebusch, **p. 103.**

Sur le Champ Magnétique et L'Inductance d'une Spire Circulaire (The Magnetic field and the inductance of a circular **helix**).—P. Bunet, **p. 522.**

The Measurement of **High D.C.** Potential Differences with Applications to the Calibration of Electroscopes and Electrostatic Voltmeters.—W. Bender, **p. 583.**

The Measurement of Choke Coil **Inductance.**—C. A. Wright and F. T. Bowditch, **p. 346.**

The Measurement of Choke Coil **Inductance.**—Wright and Bowditch, **p. 523.**

Mutual **Inductance** in Radio Circuits.—L. Hartshorn, **p. 289.**

The Establishment of Formulæ for the Self-**inductance** of Single-turn Circuits of Various Shapes.—R. G. Allen, **p. 346.**

Abbreviated Method for Calculating the **Inductance** of Irregular Plane Polygons of Round Wire.—V. J. Bashenoff, **p. 104.**

A Description of **Inductances** and the Calculation of the Value of Inductances of the Air Core Type.—F. F. Rider, **p. 522.**

Scientific **Instruments** at Olympia, **p. 689.**

Electrical Measuring **Instruments** other than Integrating Meters.—C. V. Drysdale, **p. 466.**

Théorie des Appareils de Mesure Électromagnétiques et Description d'un Nouvel Appareil à Deux Fers Répulsifs (Theory of electromagnetic measuring **instruments**, and description of a new instrument with two repelling iron elements).—S. S. Held, **p. 644.**

A Bridge Method for the Measurement of **Inter-electrode** Admittance in Vacuum Tubes.—E. T. Hoch, **p. 346.**

International Comparison of Radio-frequency Standards: Testing and adjusting Piezo Oscillators, **p. 402.**

Loop Permeability in **Iron** and the Optimum Air-gap in an Iron Choke with D.C. Excitation.—A. A. Symonds, **p. 645.**

Electrical Resistance and Magnetic Permeability of **Iron** Wire at Radio Frequencies.—G. Wait, F. Brickwedde, and E. Hall, **p. 228.**

A New Universal **Long-wave** Radio Intensity Measuring Set.—J. Hollingworth, **p. 345.**

Dielectric **Losses** in Single Layer Coils at Radio Frequencies.—W. Jackson, **p. 346.**

Some Output Power Measurements on a Moving Coil Drive **Loud Speaker.**—Clark and Bligh, **p. 645.**

Magnetostriction Oscillators.—G. W. Pierce, **p. 643.**

Messung von Magnetischen Feldern und Feldänderungen mit dem Megnetron (Measurement of Magnetic Fields and Field-changes by the **Magnetron**).—M. Rössiger, **p. 689.**

The **Measurement** of Capacitance in Terms of Resistance and Frequency.—Ferguson and Bartlett, **p. 583.**

The Application of a Valve Amplifier to the **Measurement** of X-Ray and Photo-electric Effects.—C. E. Wynne-Williams, **p. 584.**

A Simple Method of **Measurement** of Capacity and High Resistance by means of a Thermionic Valve.—G. R. Toshniwal, **p. 583.**

Ein Instrument Zur Messung von Induktivitäten und Kapazitäten (An instrument for the **measurement** of inductance and capacity).—Täuber-Gretler, **p. 644.**

Appareil de Tableau Permettant de Mesurer par Lecture Directe les Differents Elements d'un Circuit Complexe sous Courant Alternatif (**Measuring** Instrument Reading Directly the Various Elements of a Complex A.C. Circuit).—S. S. Held, **p. 688.**

Die Berechnung der akustischen Eigenschaften des Kondensatormikrophons (Calculating the acoustic properties of the condenser **microphone**).—A. J. Jakowleff, **p. 228.**

General Method for Plotting **Modulation** Characteristics of Radio Telephone-Transmitters.—N. D. Smirnov, **p. 689.**

The **Natural Period** of Linear Conductors.—C. R. Englund, **p. 583.**

The Use of the Cathode-ray **Oscillograph** in the Study of Resonance Phenomena in Piezo-electric Crystals.—K. S. Van Dyke, **p. 227.**

On the Testing of Audio-Frequency Transformers by means of the Cathode-Ray **Oscillograph.**—M. Kobayashi, **p. 346.**

The Harmonic Comparison of Radio-Frequencies by the Cathode-Ray **Oscillograph.**—T. S. Rangachari, **p. 346.**

Impiego dell'Oscillografo nello Studio delle Correnti Radiotelegrafiche (The employment of the **oscillograph** in the study of the currents of radiotelegraphy).—G. Pesson and T. Gorio, **p. 103.**

The Application of the **Phonodeik** in Determining the Performance of Electro-acoustic Devices.—Miller and Martin, **p. 584.**

On the Determination of the **Piezo-electric** Constant of a Quartz Resonator at High Frequency.—T. Fujimoto, **p. 227.**

Piezoelektrische Kristalle als Frequenznormale (**Piezo-electric** Crystals as frequency standards).—E. Giebe and A. Scheibe, **p. 289.**

Stabilisateurs de Fréquence Piézo-électriques pour Emetteurs d'Ondes Courtes (**Piezo-electric** frequency-stabilisers for short-wave transmitters).—J. Jammet, **p. 289.**

A New Type of Standard Frequency **Piezo-Electric** Oscillator.—Wheeler and Bower, **p. 643.**

Piezo-electric Oscillators and Piezo-electric Frequency Stabilisers.—Y. Watanabe, **p. 36.**

Frequency Stability of **Piezo-electric** Quartz.—P. Vecchiacci, **p. 643.**

Le Quartz Piezo-électrique Comme Etalon de Fréquence (**Piezo-electric** quartz as frequency standard).—R. Jouaust, **p. 166.**

Piezo-electric Resonance and Oscillatory Phenomena with Flexural Vibrations in Quartz Plates.—J. R. Harrison, **p. 104.**

Der **piezoelektrische** Resonator in Hochfrequenzschwingungskreisen (The **piezo-electric** resonator in high-frequency oscillatory circuits).—Y. Watanabe, **p. 289.**

Piezo-electricity. (See also under Gen. Phys.).

Über Ponderomotorische Wirkungen des Lichtes auf Ungeladene Submikroskopische Körper im Elektrischen Felde (**Ponderomotive** effect of Light on uncharged submicroscopic bodies in electrical fields).—G. Placzek; and Zum Problem des Radiometers (The Radiometer Problem).—I. Bleibaum, **p. 584.**

A Non-inductive **Potential Divider** of High Precision, **p. 644.**

Mounting **Quartz** Oscillator Crystals.—R. C. Hitchcock, **p. 37.**

Some Practical Applications of **Quartz** Resonators, **p. 289.**

Some Practical Applications of **Quartz** Resonators.—Cobbold and Underdown, **p. 583.**

Measurements of **Radiant Energy** by Means of the Maxwell-Bartoli Forces.—del Nunzio, **p. 584.**

Radiation and Induction.—Ramsey and Dreisback, **p. 644.**

Calculation of Radiation Resistance for Directive **Short-wave** Antennæ.—A. Pistolkors, **p. 584.**

A Radio **Signal-Intensity** Recorder.—B. Saltmarsh, **p. 37.**

A Short Survey of some Methods of Radio **Signal Measurement.**—K. Sreenivasan, **p. 289.**

A Short Survey of Some Methods of Radio **Signal Measurement.**—K. Sreenivasan, **p. 346.**

The Use of a Wente Condenser Transmitter to Measure **Sound Pressures** in Absolute Terms.—A. J. Aldridge, **p. 688.**

Zur Berechnung der Schall energie (The Calculation of **Sound** Energy).—V. Weisskopf, **p. 688.**

Die Scheinbare Änderung der Dielektrizitätskonstante Technischer Isolierstoffe (Apparent variation in **specific inductive capacity** of insulating materials in practical use).—P. Böning, **p. 523.**

On the Mounting of Wires in **String-electrometers.**—W. Clarkson, **p. 644.**

Apparatus Standards of **Telephonic** Transmission, and the Technique of Testing Microphones and Receivers.—B. S. Cohen, **p. 289.**

Über eine Neukonstruktion der Linear Thermosäule (A new construction of the Linear **Thermopile**).—H. Keefer, **p. 643.**

Thermostat Design for Frequency Standards.—W. A. Morrison, **p. 583.**

Data on the Voltage Amplification of Radio Frequency **Transformers.**—B. K. Osborn, **p. 523.**

Druckmessung in Vakuumglühlampen Mittels Ausseneelektrode (**Vacuum** measurement in incandescent lamps by the use of an external electrode).—Alterthrum and Ewest, **p. 645.**

Hochvakuum-Messeinrichtung für Grossgleichrichters (High **Vacuum** Indicator for large Rectifiers).—W. Menger, **p. 689.**

Methoden der Vakuumbestimmung an Fertigen Glühlampen (Methods of Determining the **Vacuum** of a Completed Incandescent Lamp).—P. Selenyi, **p. 683.**

A Direct-reading **Valve Tester.**—M. G. Scroggie, **p. 645.**

Continuous Reading of **Varying Potentials** by Means of Thermionic Valves.—D. T. Harris, **p. 467.**

A Thermionic **Voltmeter** for Measuring the Peak Voltage and the Mean Value of an Alternating Voltage of any Waveform.—G. B. Moullin, **p. 584.**

The Valve **Voltmeter** for the Measurement, Without Loss, of High Tensions.—L. Weisglass, **p. 644.**

On the Bridge Type of Valve **Voltmeter.**—I. Yamamoto and K. Morita, **p. 103.**

Mesure de L'Indice de Réfraction de L'Eau pour les Ondes Entretenues Courtes (Measurement of the index of refraction of **water** for short undamped waves).—Martey and Jones, **p. 522.**

The Measurement of the Departure of a **Wave Form** from the Sine-wave Form.—Benischke and Hammerer, **p. 584.**

Das Mass der Abweichung einer Wellenform von der Sinus-Welle (The Measurement of the departure of a **waveform** from the sine-wave form), **p. 522.**

A Method of **Wavelength** Measurement by Means of Piezo-quartz.—V. S. Gabel, **p. 523.**

Sulla Misura della Lunghezza d'Onda (**Wavelength** Measurement).—Pession and Gorio, **p. 643.**

Substandard **Wavemeter** Design.—W. H. F. Griffiths, **p. 466.**

Description of a Valve **Wavemeter** with Range of 10 Metres to 20,000 Metres.—F. M. Colebrook, **p. 37.**

L'Etalonnage Absolu des Ondemètres (Absolute calibration of **wavemeters**).—P. Olivet, **p. 37.**

SUBSIDIARY APPARATUS.

L'Accumulateur Léger (The Light-weight **Accumulator**).—J. Granier, **p. 405.**

Du Fonctionnement et de l'entretien des Accumulateurs (The Working and Maintenance of **Accumulators**).—M. Devauchelle, **p. 405.**

The Measurement of **Acoustic** Impedance and the Absorption Coefficient of Porous Materials.—E. C. Wente and E. H. Bedell, **p. 229.**

Eine Neue Methode Unmittelbarer Steuerung der Luft Durch Elektrische Schwingungen (A new method of direct control of **air** by electric oscillations).—Brenzinger and Dessauer, **p. 645.**

Ein Wechselstromkompensator mit Grossen Frequenzumfang (An A.C. compensator with wide frequency-range).—K. Lion, p. 585.
Flexible Power Operated **Amplifier.**—W. H. Fortington, p. 524.
Note sur Quelques Perfectionnements des Amplificateurs à Courant Continu (Some improvements in **amplifiers** for continuous current).—Jouaust and Décaux, p. 584.
Gleichstrom-Hochspannungsmaschinen als Anoden generatoren (High-voltage, direct-current machines for **anode-potential** supply in transmitters).—E. Rappel, p. 290.
Gleichstrom-Hochspannungsmaschinen als Anodengeneratoren (D.C. high-tension machines for **anode supply**).—H. Schulthess, p. 690.
Generator for **Audio Currents** of Adjustable Frequency with Piezo-electric Stabilisation.—A. Hund, p. 347.
Note sur un Montage de Deux Lampes Amplificatrices en Pont Equilibré (Note on a Balanced **Bridge** Valve Circuit).—H. Copin, p. 646.
More Powerful **Cathode Rays**, p. 690.
Primary Wet **Cells.**—A. M. Codd, p. 585.
Paper versus Mica **Condensers** in Radio Frequency Circuits.—J. G. Uzmann, p. 468.
An Improved **Co-ordinator.**—R. A. Castleman, Jnr., p. 403.
Laboratory **Curve** Tracer, p. 525.
Avertisseur Auto-alarme Système S.F.R.-Chauveau (Automatic **Distress** Call System S.F.R.-Chauveau), p. 690.
Dry Cells and Batteries, U.S. Government Master Specification for, p. 525.
A Modern Photographic **Electrograph.**—R. E. Watson, p. 523.
The Quadrant **Electrometer.**—J. F. Sutton, p. 523.
Ein Elektrometer Für Messung Sehr Hoher Gleich- und Wechselspannungen (An **Electrometer** for very high direct and alternating potentials).—Starke and Schroeder; also "A Simple Arrangement for Measuring High Electric Potentials."—H. Dember, p. 585.
The Universal H.T. Battery **Eliminator.**—N. P. Vincer-Minter, p. 228.
An Economical 171 B-**Eliminator** (An Economical power-mains adapter for anode supply of Receivers).—J. R. Francis, p. 524.
Surges in **Eliminator** Smoothing Circuits.—A. G. Warren, p. 690.
Back-coupling in **Eliminators.**—W. I. G. Page, p. 646.
Smoothing Condensers in **Eliminators**, p. 290.
Le Problème du Filtrage (The **Filter** Problem).—P. Olinet, p. 468.
On the "Mistuning" of Weighted **Forks.**—W. R. Miles, p. 525.
Sur le Démultiplicateur de Fréquence Ferromagnétique (The ferromagnetic **frequency** sub-multiplier).—M. Rouelle, p. 229.
Sur quelques Propriétés du Démultiplicateur (On some properties of the **frequency** sub-multiplier).—E. Rouelle, p. 290.
A New Quick-tuning Vibration **Galvanometer** with Calibrated Tuning.—D. C. Gall, p. 404.
Some Experiments on **Geiger** Ion Counters.—R. D. Bennett, p. 585.
On the Action of the **Geiger** Counter.—L. F. Curtiss, p. 690.
Some Further Uses for the Neon **Grid-glow** Tube.—Wilkins and Friend, p. 524.
The **Grid-glow**-valve Relay.—D. D. Knowles, p. 645.
Der Harmonische Analysator, ein neues Planimeter (The **harmonic Analysator**, a new planimeter).—K. Trott, p. 645.
Demonstration of a Portable Electric **Harmonic Analyser**, showing the Measurement of Harmonics in Voltage and Current Waves.—R. T. Coe, p. 528.
American Society for Testing Materials: Report of Committee D.9 on Electrical **Insulating** Materials, p. 525.
Renseignements sur une Nouvelle Matière Isolante pour la Haute Tension (Information on a new high tension **insulating** material).—W. Meyer, p. 585.
Die Verluste in Geschichteten Isolierstoffen (Losses in stratified **insulating** material).—W. Burstyn, p. 646.
Un Nouvel Isolant—la Thiolite (A new **insulating** material, Thiolite). p. 585.
Höchstspannungsisolatoren Hoher Lebensdauer aus Organischem Werkstoff (Extra high tension **insulators** of organic materials).—O. Scheller, p. 646.
Notes on the Design of Radio **Insulators.**—T. Walmsley, p. 347.
The **Inverted** Vacuum Tube, a Voltage-reducing Power Amplifier.—F. E. Terman, p. 348.
Notes on the Design of **Iron-core** Reactances which Carry Direct Current.—D. E. Replogle, p. 468.
The **Jet-wave** and its Applications.—J. Hartmann; and Die Konstruktive Durchbildung des Quecksilber-Wellenstrahl-Gleichrichters (The development of the Mercury-Jet-Wave-Rectifier). p. 646.
The **Klydonograph.**—J. Fallow, p. 467.
lechanical Production of Short Flashes of **Light.**—J. W. Beams, p. 467.
ome New Methods of **Linking** Mechanical and Electrical Vibrations.—W. H. Eccles and W. A. Leyshon, p. 524.
ome New Methods of **Linking** Mechanical and Electrical Vibrations.—Eccles and Leyshon, p. 645.
quids as Insulators.—F. M. Clark, p. 347.
ory of the Hornless **Loud Speaker**, p. 104.
oud Speaker Location.—A. H. Davis, p. 472.
Motional Impedance Characteristics of a **Loud Speaker** with a very small Horn.—S. Nakai, p. 347.
Un Nouveau Haut-Parleur (A new **loud speaker**), p. 290.
Exponential **Loud Speaker** Horns.—A. Dinsdale, p. 37.
Über Bau und Anwendung von Grosslautsprechern (Design and application of large **loud speakers**).—F. Trendelenburg, p. 347.
Loud Speakers of High Efficiency and Load Capacity.—C. R. Hanna, p. 347.
L'Evolution et L'Avenir des Haut-Parleurs (The Evolution and Future of **Loud Speakers**).—P. Toulon, p. 687.
An Experimental Investigation of Some Characteristics of **Loud Speakers.**—A. Kharkevitch, p. 524.
Methods for Investigation of **Loud Speakers.**—p. 471.
The Design of the Field Magnet, Field Strength and Leakage Flux in Moving Coil **Loud Speakers.**—A. P. Castellain, p. 524.
Resonance in Moving Coil **Loud Speakers**: The Important Influence of the Diaphragm Surround, and its Quantitative Analysis.—N. W. McLachlan, p. 687.
Beschrijving van een Toongenerator . . . (Description of a L.F. **generator**).—B. F. J. Groeneveld, p. 524.
"**Mains**" Radio Apparatus, p. 524.
A German H.T. **Mains Unit** with Glow Discharge Rectifier, p. 347.
The **Mains** Danger and the Mains and the Earth Connection (Some Considerations when obtaining Power from D.C. Supplies), p. 469.
Safety and the **Mains**: Precautions to be Taken when using Battery Eliminators.—P. R. Coursey, p. 468.
Deux Exemples de Montages qui font Intervenir la Variation des Charactéristiques d'un Appareil Récepteur ou de Mesure (Two examples of methods of connection which introduce variation of the characteristics of a receiving or **measuring** instrument).—L. Cagniard, p. 523.
Über die Beseitungen der Hochfrequenzstörungen, hervorgerufen durch einen Quecksilberdampf-Gleichrichter (On the elimination of the high-frequency disturbances produced by a **mercury vapour** rectifier).—G. Leithäuser, p. 38.
Steuerung von Elektronenströmen in Quecksilberdampfentladungen (Control of electron currents in **mercury vapour** discharges).—E. Lübcke, p. 229.
Die Anwendung der Quecksilberdampfröhre als Schaltorgan (The employment of the **mercury vapour** tube as a switch).—H. Schuchmann, p. 166.
Microphone Amplifiers and Transformers.—H. L. Kirke, p. 525.
Neuere Untersuchungen an Kohlemikrophonen (New Investigation of Carbon **Microphones**).—C. A. Hartmann, p. 690.
Microphone Electrocapillaire (Electrocapillary **microphone**).—M. Latour, p. 289.
Untersuchungen über Monotelephone (Research on **mono-telephones**).—R. Bauder and A. Ebinger, p. 290.
Moving Coil Modifications.—L. E. T. Branch, p. 581.
The Output Stage and the **Moving Coil**: How Relative Impedances affect Quality.—N. W. McLachlan, p. 581.
An Application of the Vacuum Tube **Oscillator.**—C. B. Crofutt, p. 37.
L'Extension des Applications de l'Oscillographe Cathodique de Dufour (The extended application of the Dufour Cathode-ray **Oscillograph**).—K. Berger, p. 525.
Uber einen Kathodenoszillographen hoher Spannungsempfindlichkeit (A Cathode-ray **Oscillograph** of high Voltage-sensitivity).—E. Sommerfeld, p. 689.
A Portable **Oscillograph** Equipment for the Observation of Transient Electrical Phenomena.—P. R. Coursey, p. 690.
Empfindlicher Glühkathodenoscillograph für Innenaufnahmen in einen Vorvakuum (A sensitive Hot Cathode **Oscillograph** for internal Photography in an ante-vacuum.)—W. Rogowski, E. Sommerfeld and W. Wolman, p. 690.
A Portable Cathode Ray **Oscillograph**, p. 467.
Eine Neuerung am Kathodenoszillographen (A new form of Cathode-ray **Oscillograph**).—P. Selényi, p. 467.
An Amplifier to Adapt the **Oscillograph** to Low-current Investigations.—S. K. Waldorf, p. 584.
An Improved Form of Cathode Ray **Oscillograph.**—R. H. George, p. 228.
Ein Glühkathodenoszillograph für Vakuumaufnahmen (An incandescent cathode **oscillograph** for vacuum recording).—W. Rogowski and K. Baumgart, p. 347.
Über die Verwendung der negativen Ladung der Kathodenstrahlen als Schreibmittel im Kathodenoszillographen (On the employment of the negative charge of the cathode beam as the recording means in the cathode **oscillograph**).—P. Seléngi, p. 347.
Folgeschaltungen für Kathodenstrahl-oszillographen (Sequence-switching for Cathode-ray **Oscillographs**), p. 468.
Sur l'adaptation des Oscillographes Bifilaires à l'étude des lampes triodes (The adaptation of bifilar **Oscillographs** to the study of three-electrode valves).—André Blondel, p. 404.
Cathode-ray **Oscillographs** and their Uses.—E. S. Lee, p. 645.
Das Oszilloskop (The **Oscilloscope**).—Bedell and Reich, p. 404.
Paxolin.—W.I.G.P., p. 167.
Über Materialien mit Hoher Anfangspermeabilität (Materials of high initial **permeability**).—Yensen and Gumlich, p. 646.
Magnetic Properties of **Perminvar.**—G. W. Elmen, p. 646.

Instruction on the Making of Potassium Hydride **Photo-Electric** Cells.—W. B. Nottingham, **p. 467.**
Characteristics of **Photo-electric** Tubes.—Koller and Breeding, **p. 645.**
L'Emploi de Cellules Photoelectriques, associées à des Lampes à plusieurs Électrodes, à la Solution de divers Problèmes concernant la Mesure du Temps (The Use of **Photo-Electric** Cells associated with multi-electrode Valves, for the solution of various Time-measuring Problems).—G. Ferrié and R. Jouaust, **p. 689.**
The Element of Time in the **Photo-Electric** Effect.—E. O. Lawrence and J. W. Beams, **p. 689.**
Photo-electricity. (*See also under* General Physical and Miscellaneous.) A Vacuum Tube **Potentiometer.**—A. L. Fitch, **p. 37.**
Development of a System of Line **Power** for Radio.—G. B. Crouse, **p. 646.**
Safeguarding Batteries and Valves: How to Use **Protective** Fuses. **p. 405.**
Protection of . . . Lines against Over-Voltage.—E. Beck, **p. 404.**
An Automatic **Recorder** for Measuring the Strength of Radio Signals and Atmospheric Disturbances.—E. B. Judson, **p. 467.**
The Hall High-speed **Recorder, p. 646.**
The Sulphide **Rectifier:** An Explanation of its Functioning and its Application to Radio and Industrial Uses.—H. Shoemaker, **p. 468.**
Metal **Rectifiers, p. 37.**
Redresseur "Oxymétal" pour courant alternatif, à rondelles de cuivre oxydé ("Oxymetal" **Rectifier,** for alternating current, comprising washers of oxidised copper).—C. Chouquet, **p. 404.**
Redresseur à Simple Effet ou Redresseur à Double Effet? (Half wave or full wave **rectifier**?)—A. Vernay, **p. 585.**
The Vacuum Tube **Rectifier:** Oscillographic and Vacuum Tube Voltmeter (Study of its Application to B-Voltage Supply for Radio Receivers).—J. Kuhlmann and J. Barton, **p. 166.**
Metal **Rectifiers, p. 468.**
Das Glimmlichtrohr Als Gleichrichter von Wechselströmen (Blue-glow valves as A.C. **Rectifiers).**—G. Seibt, **p. 585.**
Die Trockenplatten-Gleichrichter (The dry-plate **rectifiers).**—H. Fröhlich, **p. 405.**
Oszillographische Untersuchungen an Gleichrichtern (Oscillographic Tests on **Rectifiers).**—G. Tenzer, **p. 646.**
Construction Pratique et Utilisation des Soupapes au Tantale (Practical Construction and Use of Tantalum **Rectifiers).**—Chardon, **p. 524.**
Étude des Valves de Refressement (**Rectifiers** of valve form).—Y. Doucet, **p. 585.**
Thin-film **Rectifiers.**—J. Slepian, **p. 229.**
Sur l'Effet de Soupape Présenté par les Électrodes en Silicium (**Rectifying** effect of silicon electrodes).—M. Aubert, **p. 404.**
A New Type of **Selenium** Cell.—R. E. Martin, **p. 403.**
Constant **Speed** Mechanism for an Accuracy of 1 in 10,000. (See Miscellaneous, "Picture Reception"). **p. 468.**
The Problem of Radio Set Power **Supply.**—G. B. Crouse, **p. 524.**
L'Alimentation des Postes Récepteurs (The **supply** of electricity to receiving sets).—J. Granier, **p. 404.**
Ein Gleichstrom-Wechselstrom-Umformer für jene, die ein Gleichstrom-Lichtnetz in ihrer Wohnung haben (a D.C.-A.C. converter for use on D.C. power **supply).**—F. Gabriel, **p. 690.**
Ein Wechselstrom-Netzanschlussgerät zur Gleichzeitigen Entnahme der Heiz und der Anodenspannung (An arrangement for obtaining heating- and Anode-voltage simultaneously from the public A.C. **supply).**—J. Schad, **p. 405.**
L'Alimentation des Postes de T.S.F. (The **supply** of electricity to Radio-stations).—P. Olinet, **p. 405.**
The Direct-current Transformer Utilising **Thyratron** Tubes.—D. C. Prince, **p. 585.**
Bridge for Measuring Small **Time** Intervals.—J. Herman, **p. 405.**
Die Erzeugung sehr hoher Gleichspannung (The production of **very high** D.C. voltage).—E. Marx, **p. 645.**
An Optical Method of Measuring Small **Vibrations.**—H. A. Thomas and G. W. Warren, **p. 404.**
Automatic **Voltage-Stabiliser** for Apparatus Fed from A.C. Mains.—Soulié, **p. 468.**
Nouveau Dispositif Stabilisateur de Tension, Système Soulier (New arrangement for stabilisation of **voltage,** system Soulier), **p. 584.**
Ein Empfindliches Röhrenvoltmeter für Hochfrequenz (A sensitive Valve-**Voltmeter** for High Frequency).—M. von Ardenne, **p. 405.**
A Compensated Electron-tube **Voltmeter.**—H. M. Turner, **p. 524.**
Further Notes on the Reflex **Voltmeter.**—W. B. Medlam and U. A. Oschwald, **p. 166.**
A Two-range Vacuum Tube **Voltmeter.**—C. Jansky, Jr., and C. Feldman, **p. 228.**
The Development of the Hot Cathode **X-Ray** Tube, **p. 524.**

STATIONS, DESIGN AND OPERATION.

London's New **Air Port.**—W. G. W. Mitchell, **p. 290.**
Technisches Nachrichtenwesen in der Reichswehr (Communication-technique in the National **Army).**—Pleger, **p. 690.**
The "Empiradio" **Beam** Stations, **p. 348.**
La Radiotéléphonie par Ondes Courtes Projetées: les Premières Communications entre Paris et Alger (Radiotelephony by short-wave **beam;** the first communications between Paris and Algiers).—R. Nöel, **p. 405.**
Un Système Français D'Émission à Ondes Courtes Projetées (A French system of short-wave "**beam**" transmission).—M. Chireix, **p. 468.**
La Transmission Radiotéléphonique par Ondes Courtes Dirigées et la Station D'Essais de Communication Paris-Alger (Radiotelephonic transmission by short-wave "**beam**" and the trial station for the Paris-Algiers service).—R. Villem, **p. 469.**
Liaisons Radiotéléphoniques à Grande Distance par Ondes Courtes Projetées (Long-distance radiotelephonic communication by short-wave **beam).**—H. Chireix, **p. 647.**
Wireless Equipment of the Motor ship "**Bermuda,**" **p. 167.**
Broadcast Control Operation.—Carl Dreher, **p. 348.**
The Design and Distribution of Wireless **Broadcasting** Stations for a National Service.—P. P. Eckersley, **p. 406.**
The Design and Distribution of Wireless **Broadcasting** Stations for a National Service, **p. 290.**
World **Broadcasting:** 1,116 Stations, **p. 229.**
220-Kv. **Carrier**-Telephony.—R. B. Ashbrook and R. E. Henry, **p. 290.**
5SW, **Chelmsford, p. 104.**
Simultaneous Broadcasting in **Czecho-Slovakia.**—E. K. Sandeman, **p. 229.**
La Direction des Ondes Radioélectriques: Idées et Réalisations Récentes (The **direction** of radioelectric waves: recent ideas and results).—L. Bouthillon, **p. 647.**
The **Dutch** Short-wave Station, **p. 229.**
Egypt: Radio Telegraphy, **p. 167.**
Radio in **France, p. 167.**
Régulateur Automatique de Fréquence pour Postes Émetteurs à Ondes Courtes (Automatic **Frequency** Regulator for Short-wave Transmitting Stations,) **p. 690.**
Note on the Effective **Heating** of Code Transmitters.—F. E. Terman, **p. 586.**
Die Störbefreiung in der Drahtlosen Telegraphie nach dem Verfahren "Baudot-Verdan" (The prevention of **interference** in Wireless Telegraphy by the "Baudot-Verdan" System), **p. 406.**
Der Neue Deutschland-Sender bei **Königswusterhausen** (The new "Germany transmitter at . . .").—W. Kummerer, **p. 406.**
Der Deutschlandsender bei Königswusterhausen (The "Deutschland" transmitter near **Königswusterhausen).**—W. Meyer, **p. 290.**
Stato Attuale delle Stazioni Trasmittenti a Onde Lunghe (Present condition of **long-wave** transmitting stations).—R. Hirsch, **p. 229.**
A Propos de la **Multicommunication** par très Courtes Ondes Électriques.—A. Turpain, **p. 647.**
Multicommunication Généralisée par tres Courtes Ondes Électriques (**Multiplex** communication by very short waves).—A. Turpain, **p. 586.**
Short Wave **Multiplex** System of Radio Communication.—Marconi-Mathieu, **p. 525.**
Postes Portatifs à Ondes Courtes (**Portable** short-wave stations), **p. 586.**
La Station Radiotéléphonique de Prague (The **Prague** broadcasting station).—E. M. Deloraine, **p. 290.**
Wireless Masts and **Screening.** (1. The Aerial Support and its Effect on Signal Strength; and 2. Some Considerations in Erecting a Broadcast Receiving Aerial).—R. L. Smith-Rose, **p. 406.**
Seaforth Radio Station.—W. M. Osborn, **p. 348.**
Short-Wave Transmissions, **p. 290.**
I Moderni Trasmettitori ad Onde Corte per Servizi Commerciali (Up-to-date **short-wave** transmitters for commercial services).—M. Cabrini, **p. 229.**
Some Investigations of **Short Waves** at Nijni-Novgorod.—W. W. Grzybowski, **p. 468.**
A **Super-receiving** Station.—A. Dinsdale, **p. 167.**
Radio in **Sweden, p. 167.**
Transatlantic Success on 10 Metres: A Description of the Apparatus used in Successful Two-way Amateur Communication.—P. Auschitzky, **p. 586.**
The Cupar Receiving Station of the **Transatlantic** Telephone Systems, **p. 586.**
Transatlantic Telephony—The Technical Problem.—O. B. Blackwell, **p. 408.**
Transatlantische Telephonie (**Transatlantic** Telephony).—F. Anton, **p. 469.**
United States: Radio Telegraphy, **p. 167.**

GENERAL PHYSICAL ARTICLES.

Untersuchungen uber den Mechanismus des Lichtbogens (Investigation of the Mechanism of the Electric **Arc** Discharge).—R. Seeliger, **p. 527.**
Physico-chemical Considerations in **Astro-physics.**—W. Nernst, **p. 586.**
What is an **Atom**?—P. R. Heyle, **p. 470.**
Direct Evidence of **Atom** Building.—Millikan and Cameron, **p. 469.**
Report of Work of **Bartol** (Research) Foundation.—W. F. G. Swann, **p. 469.**
Report of Work of **Bartol** (Research) Foundation.—W. F. G. Swann, **p. 527.**

The Study of the Specific Resistance of **Bismuth** Crystals and its Change in Strong Magnetic Fields, and Some Allied Problems.—P. Kapitza, p. 469.
Uber das Verhalten von Wismutschichten in Magnetfeld (The behaviour of **Bismuth** leaf in a magnetic field).—F. Gross, **p. 647.**
The **Boltzmann-Hopkinson** Principle of Super-position as applied to Dielectrics.—F. D. Murnaghan, **p. 168.**
Untersuchungen über den Elektrischen Durchschlag und Überschlag in unhomogenen Felde (Investigations of Electrical **Breakdown** and Flashover in a Field which is not Homogeneous).—E. Marx, p. 692.
Influence of Weak Magnetic Fields on the Degree of Polarisation of the Light Emitted by Hydrogen **Canal Rays.**—v. Traubenberg, **p. 527.**
Kathodenzerstäubungsprobleme (**Cathode** Sputtering).—Blechschmidt and v. Hippel, **p. 648.**
Temperature of the **Cathode** as a Factor in the Sputtering Process.—L. R. Ingersoll and L. O. Sordahl, **p. 693.**
Kathodenzerstäubung (Wearing-away of **Cathodes** by emission of particles) p. 470.
The **Compton** Effect and Polarisation.—P. Lukirsky, **p. 586.**
Thermodynamics, Wave-Theory, and the **Compton** Effect.—C. V. Raman, p. 105.
A Suggested Theory of Electric **Conduction.**—W. H. McCrea, **p. 587.**
Electrical **Conductivity.**—W. V. Houston, **p. 469.**
On the Kinetic Method in the new Statistics and its Application in the Electron Theory of **Conductivity.**—L. W. Nordheim, **p. 526.**
Sur L'Effet Volta (On the " Volta " Effect of **Contact** Potential).—A. Cotton, p. 525.
Corpuscular Theory.—G. Forbes, **p. 648.**
The Abnormal Specific Heat of a Rarified Gas at a Low Temperature: and the **Cosmic** Radiation.—R. D. Kleeman, **p. 691.**
New Results on **Cosmic Rays.**—R. A. Millikan and G. H. Cameron, p. 167.
The Highly Penetrating **Cosmic** Rays.—A. Corlin, **p. 230.**
High Altitude Tests on the Geographical, Directional and Spectral Distribution of Cosmic Rays.—R. Millikan and G. Cameron, **p. 230.**
Cosmic Rays, p. 469.
The Origin of the **Cosmic** Rays.—R. A. Millikan and G. H. Cameron, p. 691.
The Wider Aspects of **Cosmogony.**—J. H. Jeans, **p. 290.**
Evidence for the Continuous **Creation** of the Common Elements out of Positive and Negative Electrons.—Millikan and Cameron, p. 526.
Der selbsttönende **Kristall als thermischer Effekt** (The spontaneously singing **crystal** as a thermal effect).—F. Seidl, **p. 38.**
Preferred Orientation in Tungsten **Crystals** caused by Mechanical Working.—H. De Vore and W. Darcy, **p. 168.**
Sur la Constante Diélectrique du Benzite (The **dielectric constant** of benzil) —L. Saint Antoine, **p. 591.**
Étude Expérimentale et Théorique de la Variation des Constantes Diélectriques de Quelques Liquides avec la Pression (Variation with pressure of **dielectric constants** of certain liquids).—L. Cagniard, **p. 589.**
Beeinflussung der Dielektrizitätskonstanten durch elektrostatische Felder (The influencing of **dielectric constants** by electrostatic fields).—F. Kautzsch, **p. 348.**
A Theory of Imperfect Solid **Dielectrics.**—M. G. Malti, **p. 104.**
Integraph Solution of **Differential** Equations.—V. Bush and H. Hazen, p. 39.
Experiments on the **Diffraction** of Cathode Rays.—G. P. Thomson, p. 526.
The **Diffraction** of Electrons by a Crystal of Nickel.—C. J. Davisson, p. 230.
Versuche Über Elektronenbeugung am Optischen Gitter (Experiments on the **diffraction** of electrons at an optical grid).—E. Rupp, **p. 648.**
Theorie Moleculaire de la Diffusion de la Lumiere par les Fluides (Molecular Theory of the **Diffusion** of Light by Fluids).—Y. Rocard, p. 692.
The Character of the **Discharge** in an Air Gap submitted to a Steep Fronted Potential Wave.—Mochizuki and Murakami, **p. 693.**
Note on the Rôle of Positive Ions in the Disruptive **Discharge.**—J. Townsend, **p. 230.**
The High-frequency Electric **Discharge** at Low Pressures.—J. Taylor and W. Taylor, **p. 407.**
Stossspannung und Durchschlag bei Gasen (Shock-voltage and **Discharge** through Gases).—W. Rogowski; and Breakdown of Spark Gaps.—J. Slepian, **p. 527.**
Sur la Contraction Gazeuse de l'Hydrogène Soumis à la Décharge Électrique (The gaseous contraction of hydrogen under electric **discharge**).—R. Delaplace, **p. 587.**
Die Abhängigkeit des Normalen Kathodenfalles der Glimmentladung von der Gasdichte (The dependence of the normal cathode fall of the glow—Geissler—**discharge** on the gas pressure).—A. Güntherschulze, **p. 587.**
Application des Lois de l'Ionisation a l'Étude de la Décharge dans les Gaz Rarifiés (Application of the laws of ionisation to the study of the **discharge** in rarified gases).—M. Morand, **p. 588.**
Some Experiments on the Auto-Electronic **Discharge.**—de Bruyne, p. 588.
De **Disperso**-Electriciteit (" Disperso-Electricity").—H. G. Bos, **p. 692.**
The **Electrodeless** Discharge through Gases.—J. J. Thomson, **p. 408.**
Electrodeless Discharges.—J. S. Townsend, **p. 168.**
Condensible Gas Modifications Formed under the Influence of **Electrodeless** Discharges.—J. Taylor, **p. 648.**
Quelques Difficultés Expérimentales de la Théorie Électromagnétique du Rayonnement de la Lumière (Some experimental difficulties in connection with the **electromagnetic** theory of light).—A. H. Compton, **p. 408.**
Electron Reflection.—S. Szczeniewski, **p. 693.**
Zur Elektronen Theorie der Metalle Nach der Fermischen Statistik (The **Electron** Theory of Metals according to the Fermi Statistics).—A. Sommerfeld, **p. 525.**
Statistical Experiments on the Motion of **Electrons** in Gases.—R. d'E. Atkinson, **p. 527.**
On the Extraction of **Electrons** from Cold Conductors in Intense Electric Fields.—O. W. Richardson, **p. 230.**
The Distribution of **Electrons** in a Metal.—J. E. Lennard-Jones and H. J. Woods, **p. 693.**
Motion of **Electrons** in Gases.—J. S. Townsend, **p. 693.**
Focussing **Electrons** reflected or emitted at Equal Angles from a Plane Surface.—D. A. Wells, **p. 528.**
The History and Recent Progress of the Theory of **Electrons.**—T. Shimizu, **p. 693.**
Über die Winkelverteilung langsamer Elektronen beim Durchgang durch Metallhaüte (The Angular Dispersion of Slow **Electrons** on Passage through Metal Films).—E. Rupp, **p. 692.**
Available **Energy.**—R. A. Millikan, **p. 691.**
A differential Retarding Potential Method for the Study of the **Energy** Distribution of Slow Electric Emissions.—C. F. Sharman, **p. 39.**
Sur les Equations du Champ Electromagnétique (On the **equations** for the electromagnetic field).—E. Brylinski, **p. 291.**
Sur les Expériences de M. Esclangon et leur Application à L'Étude des Mouvements de L'Éther à Proximité des Masses Matérielles (M. Esclangon's Experiments and their application to the study of the movements of the **ether** near material masses).——. Corps, **p. 588.**
Les idées nouvelles sur la structure de l'éther (The new ideas on the structure of the **ether**).—G. Giorgi, **p. 407.**
The Suggested Application of Ultra-micronic Oscillating Circuits to New **Ether Drift** Experiments.—H. Hamer, **p. 588.**
The **Fermi-Dirac** Hypothesis of Gas Degeneration and its Applications.—E. S. Bieler, **p. 589.**
The " Action " of an Electromagnetic **Field.**—S. R. Milner, **p. 693.**
A Determination of a Limit of the Number of **Free Electrons** in a Metal.—F. E. Colpitts, **p. 692.**
The Influence of **Gravitation** on Electromagnetic Phenomena.—E. T. Whittaker, **p. 588.**
Some Experimental Evidence Supporting the Kinetic Theory of **Gravitation.**—C. F. Brush, **p. 588.**
A Unified Theory of **Gravitation** and Electricity.—C. Snow, **p. 230.**
Gravitation and Electricity as Manifestations of a Six-dimensional World.—C. Snow, **p. 230.**
Zur Feldtheorie von Elektrizität und Gravitation (On the field theory of electricity and **gravitation**).—L. Infeld, **p. 349.**
Zur Problem Einer Einheitlichen Feldtheorie von Elektrizität und Gravitation (The problem of a uniform field theory of electricity and **gravitation**).—L. Infeld, **p. 588.**
On Electric Phenomena in **Gravitational** Fields.—E. T. Whittaker, **p. 39.**
Note on the Law that Light-rays are the Null Geodesics of a **Gravitational** Field.—E. T. Whittaker, **p. 230.**
On the Potential of Electromagnetic Phenomena in a **Gravitational** Field.—E. T. Whittaker, **p. 588.**
Theory of the Magnetic Nature of **Gravity** and Newton's Laws.—C. L. Sagui, **p. 349.**
An Electrical Method of **Harmonic Analysis.**—S. Brown, **p. 229.**
High-Frequency Currents.—E. W. Marchant, **p. 291.**
Interferenzerscheinungen bei Korpuskularstrahlen (**Interference** Phenomena in Corpuscular Radiation).—W. Elsasser, **p. 692.**
Ionisation by Collision.—L. G. Huxley, **p. 39.**
A Reply to the Paper, " **Ionisation** by Collision."—J. Taylor, **p. 168.**
Phénomènes d'Ionisation des gaz (Phenomena of **ionisation** of gases).— —. Abadie, **p. 527.**
Mercury Lamp and Radium as **Ionisers.**—Rogowski and Tamm, **p. 692.**
A New Method of Determining the Mobility of **Ions** or Electrons in Gases.—Van de Graaff, **p. 525.**
Kerr Effect in Water due to High Frequency Radio Waves.—A. Bramley, **p. 587.**
On Relaxation of Electric Fields in **Kerr** Cells and Apparent Lags of the Kerr Effect.—Beams and Lawrence, **p. 587.**
Theory of the **Kerr** and Faraday Effects in Gases. Part II. Quadratic Effects.—R. de L. Kronig, **p. 526.**
Disappearance and Reversal of the **Kerr** Effect.—C. V. Raman and S. C. Sirkar, **p. 408.**
Eine Methode zur Bestimmung der Kerr Konstante Schlecht Isolierender Stoffe mit Hilfe Elektrischer Wechselfelder (A method of determining the **Kerr** Constant of badly insulating

materials with the help of electric A.C. fields).—W. Ilberg, **p. 648.**
Demonstration of High-frequency Fluctuations in the Intensity of a Beam of **Light.**—C. O. Browne, **p. 105.**
A Proposed Experiment on the Nature of **Light.**—D. M. Dennison, **p. 586.**
A Suggested Arrangement for the Determination of the Velocity of **Light.**—N. Deisch, **p. 407.**
Remarques sur la Théorie de la Lumière, Énergie, Cohérence et Franges Supplementaires (Remarks on the theory of **Light,** Energy, coherence and supplementary fringes).—F. Wolfers, **p. 407.**
Demonstration of Partial Frequencies in **Light Waves** of Periodically Varying Intensity.—E. Rupp, **p. 587.**
The Revolution in Physics.—Oliver **Lodge, p. 692.**
On the Diffraction of the **Magnetic Electron.**—C. G. Darwin, **p. 691.**
An Attempt to Detect a **Magnetic Field** as the Result of the Rotation of a Copper Sphere at High Speed.—W. F. G. Swann and A. Longacre, **p. 692.**
On the **Magnetic Moment** of the Electron.—C. G. Darwin, **p. 691.**
The **Magnetic Moment** of the Electron.—G. Breit, **p. 691.**
Magnetic Reflection.—R. Abbott, **p. 230.**
Über den Ursprung des auf der Atomstruktur Beruhenden Magnetismus (The Origin of the **Magnetism** due to Atomic Structure). —Kotarô Honda, **p. 587.**
The Theory of Ferro**magnetism.**—W. Heisenberg, **p. 647.**
Die Magnetostriktion (**Magnetostriction**).—A. Schulze, **p. 647.**
Consequences of a **Matrix Mechanics** and a Radiating Harmonic Oscillator without the Quantum Postulate.—A. Press, **p. 104.**
La Theorie de Maxwell et L'Électricité Moderne (**Maxwell's** Theory and Modern Electricity).—L. La Porte, **p. 471.**
On **Maxwell's** Stress, and its Time Rate of Variation.—S. R. Milner, **p. 39.**
Ein Versuch der Ableitung des Maxwellschen Verteilungsgesetzes auf thermodynamischen Wege (An attempt to deduce **Maxwell's** law of distribution by thermodynamical means).—A. Schükaren, **p. 348.**
New Methods of Electrically Maintaining **Mechanical** Oscillations. —J. H. Vincent, **p. 104.**
Study of the Higher **Natural Oscillations** of Solenoidal Coils.—I. Yamamoto, **p. 104.**
Über das Auftreten von Eigenschwingungen bei Erzwungenen Bewegungen eines Linearen Harmonischen Oszillators (The production of **natural oscillations** by forced vibrations of a linear harmonic oscillator).—H. Schmidt, **p. 587.**
The **Negative** Absorption of Radiation.—Raman and Krishnan, **p. 526.**
Experimental Proof of "**Negative** Dispersion."—Kopfermann and Ladenburg, **p. 691.**
Un Nouveau Phénomène d'Optique (A new phenomenon in **Optics**). —J. Cabannes, **p. 407.**
Étude des Oscillations Entretenues (The Study of Sustained **Oscillations**).—A. Liénard, **p. 469.**
Sur les Oscillations d'Ordre Supérieur d'un Circuit Oscillant (On the **oscillations** of an oscillating circuit of higher order).—M. Chenot, **p. 290.**
Über Koppelschwingungen kontinuierlicher Teilsysteme (Coupled **oscillations** of continual partial systems).—E. Waetzmann and K. Schuster, **p. 291.**
Sur le Rôle de l'Ozone dans l'Atmosphere (On the part **ozone** plays in the atmosphere).—J. Lévine, **p. 104.**
Photo-electric Conduction in Selenium.—R. J. Piersol, **p. 38.**
Photo-electric Effect and Surface Structure in Zinc Single Crystals. —E. Linder, **p. 38.**
General Considerations on the **Photo-electric** Effect.—P. W. Bridgman, **p. 168.**
Demonstratie van een Nieuw Photoelectrisch Effect (Demonstration of a new **photo-electric** effect).—F. M. Penning, **p. 470.**
The Complete **Photo-electric** Emission from Potassium.—Jessie Butterworth, **p. 589.**
On the Mechanism of **Photo-electric** Emission.—J. H. Hsu, **p. 230.**
The **Photo-electric** Properties of Thin Films of the Alkali Metals.—N. R. Campbell, **p. 692.**
Photo-electric Thresholds and Fatigue.—G. B. Welch, **p. 689.**
Photo-electricity. (*See also under* Subsidiary Apparatus and Miscellaneous.)
The Determination of the Elastic Moduli of the **Piezo-electric** Crystal Rochelle Salt by a Statical Method.—W. Mandell, **p. 38.**
Modes of Vibration in **Piezo-electric** Crystals.—A. Crossley, **p. 349.**
Piezo-electric Excitation of Longitudinal, Transverse and Torsional Vibrations in Quartz Rods.—Giebe and Scheibe, **p. 470.**
Piezoelektrische Erregung von Dehnungs-Biegungs- und Drillungsschwingungen bei Quarzstäben (**Piezo-electric** excitation of extension, flexural and torsional oscillations in quartz rods).—E. Giebe and A. Scheibe, **p. 348.**
Quelques Modes Particuliers de Vibration des Quartz Piezo-electriques (Some particular modes of vibration of **piezo-electric** quartz plates).—R. Jouaust, **p. 348.**
Piezo-electric Quartz Resonators: An Optical Interference Method of Observing their Modes of Vibration, **p. 470.**
Sifflement Continu Produit par un Quartz Piézo-électrique émettant simultanément Deux Oscillations de Haute Fréquence (The continuous whistling produced by **piezo-electric** quartz simultaneously emitting two high-frequency oscillations).—F. Bedeau and J. de Mare, **p. 230.**
The **Piezo-electric** Resonator and its Equivalent Network.—K. S. Van Dyke, **p. 526.**
Phénomènes Optiques Présentés par le Quartz mis en Vibration Piézo-électrique (Optical phenomena presented by quartz set in **piezo-electric** vibration).—R. Moens and J. E. Verschaffelt, **p. 105.**
Mechanische Schwingungen piezoelektrisch angeregter Quarze (Mechanical oscillations of **piezo-electrically** excited quartz).—R. Wachsmuth and H. Auer, **p. 348.**
Bibliography on **Piezo-electricity.**—W. G. Cady, **p. 349.**
Piezo-electricity. (*See also under* Measurements and Standards.)
Calcul du Champ Interne de Polarisation (Calculation of the Internal Field of **Polarisation**).—de Malleman, **p. 693.**
Potential Difference and Capacity in A.C. Problems.—G. W. O. Howe, **p. 229.**
Some Further Problems in **Potential Difference.**—G. W. O. Howe, **p. 290.**
Untersuchung und Theorie der Pyroelektrizität (Investigation and theory of **Pyro-electricity**).—Meissner and Bechmann, **p. 408.**
Unidirectional **Quanta** in Wave Mechanics.—G. Breit, **p. 39.**
Polarisation Rotatoire—Calcul du pouvoir rotatoire du quartz (Rotatory Polarisation—Calculation of the rotating power of **quartz**).—de Mallemann, **p. 407.**
Théorie Electro-optique du Quartz (Electro-optical theory of **quartz**).—R. de Mallemann, **p. 348.**
Étude Expérimental des Déformations et des Changements de Propriétés Optiques du Quartz sous l'Influence du Champ Electrique (Experimental investigation of the deformations and change in optical properties of **quartz** under the influence of an electric field).—M. Ny Tsi Ze, **p. 348.**
Mechanical Oscillations of **Quartz** Crystals.—Wachsmath and Auer, **p. 470.**
The Temperature Coefficient of Oscillating **Quartz** Plates.—R. Strout, **p. 168.**
Schwingungen Piezoelektrischer Quartzstäbe Hervorgerufên Durch ein Ungleichförmig Verteiltes Feld (p.e. **quartz** rod oscillations produced by a non-uniformly distributed field).—S. J. Sokoloff, **p. 648.**
A New **Radiation.**—C. V. Raman, **p. 647.**
The **Raman** Effect in Highly Viscous Liquids.—S. Venkateswaren, **p. 691.**
Influence of Temperature on the **Raman** Effect.—K. S. Krishnan, **p. 691.**
The Relation between **Refractive Index** and Density.—D. Burnett, **p. 39.**
Radiation and **Relativity.**—G. Y. Rainich, **p. 526.**
Au sujet de la relativité et de Lorentz (Concerning **Relativity** and Lorentz).—Général Cartier, **p. 407.**
Resonance Radiation in Excited Neon.—Y. Fujioka, **p. 168.**
Versuche über die Resonanz der Reststrahlen und der Kürzesten Hertzschen Wellen (Tests on the **Resonance** of Residual Rays and the Shortest Hertzian Waves).—M. A. Lewitsky, **p. 587.**
The Temperature Variation of the Elasticity of **Rochelle** Salt.—E. P. Harrison, **p. 38.**
Sur l'État dit "Sama-Zustand" (The Condition called "**Sama-Condition**").—E. A. Holm, **p. 693.**
Wavelength Shifts in **Scattered** Light.—R. W. Wood, **p. 647.**
Wavelength Shifts in **Scattered** Light.—W. H. Martin, **p. 691.**
Negatively Modified **Scattering.**—Saha, Kothari and Toshniwal; and The Scattering of Light by Free Electrons according to Dirac's New Relativistic Dynamics.—Klein and Nishina, **p. 647.**
The **Scattering** of Positive Ions from a Platinum Surface.—R. W. Gurney, **p. 693.**
Dynamical and Electrical Problems whose Solutions satisfy **Schrödinger's** Wave Equation.—A. Bramley, **p. 39.**
The Emission of **Secondary** Electrons and the Excitation of Soft X-Rays.—O. W. Richardson, **p. 525.**
Dépolarisation des Radiations Secondaires dans la Lumière Complexe qui résulte de la Diffusion Moléculaire d'une Radiation Monochromatique (Depolarisation of **Secondary Radiations** in Complex Light, resulting from Molecular Diffusion of a Monochromatic Radiation).—J. Cabannes, **p. 691.**
The Velocity of **Sound** in Liquids at High Frequencies by the Sonic Interferometer.—Hubbard and Loomis, **p. 469.**
The Shadowgraph Method as Applied to a Study of the Electric **Spark.**—H. A. Zinszer, **p. 407.**
Stossspannungen und Funkenbilder (Shock-voltages and **Spark**-pictures).—W. Rogowski and R. Tamm, **p. 692.**
On a Photo-electric Theory of **Sparking** Potentials.—J. Taylor, **p. 168.**
Molecular **Spectra** in the Extreme Infrared.—Raman and Krishnan, **p. 588.**
The **Stark** Effect at Very High Field.—Toshio Ishida, **p. 588.**
The Photoelectric Conductivity of **Sulphur.**—B. Kurrelmeyer, **p. 104.**
Zur Theorie der Koppelschwingungenzwischen Telephonmembranen und Lufträumen (Theory of coupled oscillations between **telephone membranes** and air spaces).—K. Schuster, **p. 291.**

Note on **Thermionic** Emission.—Lewi Tonks, p. 648.
On the **Thermodynamic** Equilibrium in the Universe.—F. Zwicky, p. 587.
Evaporation of **Tungsten** under Various Pressures of Argon.—G. Fonda, p. 230.
On the **Ultra-violet** Radiations Emitted by Point Discharges.—J. Thomson, p. 648.
The Penetration of **Ultra-violet** Light into Pure Water and Sea Water.—E. O. Hulburt, p. 586.
Vektordiagramme bei Stromresonanz (**Vector** diagrams in the case of current resonance).—E. Roessler, p. 168.
The **Volta** Effect.—A. W. Porter, p. 647.
The Elements of **Wave Mechanics.**—L. M. Milne-Thomson, p. 527.
Free Motion in the **Wave Mechanics.**—C. G. Darwin, p. 105.
Contemporary Advances in Physics. XIV.—Introduction to **Wave Mechanics.**—K. Darrow, p. 39.
The Results of Classical **Wave Mechanics** obtained by using the Methods of Relativity Mechanics.—T. Lewis, p. 168.
Wave Mechanics and Radioactive Disintegration.—Gurney and Condon, p. 692.
Die erste Aussenaufnahme einer Wanderwelle (The First External Record of a **Wave-surge**).—W. Rogowski and E. Flegler, p. 692.
The **Waves** of an Electron.—G. P. Thomson, p. 526.
The Rigorous and Approximate Theories of Electrical Transmission Along **Wires**).—J. R. Carson, p. 229.
Absolute **X-Ray** Wavelength Measurements.—A. P. R. Wadlund, p. 586.
The Reflection of **X-Rays** from Glass and Quartz.—Laby, Shearer and Bingham, p. 526.

MISCELLANEOUS.

Acoustics.—A. G. Huntley, p. 695.
Über neuere akustische und insbesondere elektroakustische Arbeiten (Latest work on **acoustics**, and in particular electro-acoustics).—F. Trendelenburg, p. 695.
Le Grand Électro-**aimant** de L'Académie des Sciences.—A. Cotton, p. 529.
Aircraft Radio Installations.—M. P. Hanson, p. 590.
Bibliography on **Aircraft** Radio.—Jolliffe and Zandonini, p. 590.
Die Anwendung von kurzen Wellen im Verkehr mit Flugzeugen (The employment of short waves for communication with **aircraft**).—H. Plendl, p. 163.
Über den Widerstand von Flugzengantennen und die Dadurch Verursachte Verringerung der Flugleistungen (The resistance due to **aircraft** aerials and the consequent diminution of flying power).—F. Liebers, p. 589.
Die Vorzüge des Kurzwellen-verkehrs mit Flugzeugen (The advantages of short-wave communication with **aircraft**).—H. Fassbender, p. 589.
Zur Anwendung der Kurzen Wellen im Verkehr mit Flugzeugen : Versuche Zwischen Berlin und Madrid (The use of short waves for communication with **Aircraft** : Tests between Berlin and Madrid).—Krüger and Plendl, p. 528.
Symbolical **Algebra.**—J. A. Ratcliffe, p. 349.
Air Service and Amateur Co-operation (The **American** Coast-to-Coast Air Route Described).—H. de A. Donisthorpe, p. 410.
America's Short Wave Development, p. 471.
Valve **Amplifiers** for Submarine Cables.—A. M. Curtis, p. 39.
Laboratorien und Forschungsarbeiten der Funkabteilung der Deutschen Versuchsanstalt für Luftfahrt in Berlin-Adiershof (Laboratories and research work of the radio department of the German experimental establishment for **aviation** at Adlershof, Berlin).—H. Fassbender, p. 231.
Impressions of the **Berlin** Show, p. 650.
Quantitatives über Strassenbahnstörungen des Rundfunkempfanges (Quantitative results on the disturbance of **broadcast** reception by trams).—W. Bernitt, p. 105.
La Radiodiffusion Brittannique Décrite par elle-même (British **Broadcasting** described by itself).—L. de la Forge, p. 471.
The (Electrical) Industry as Related to **Broadcasting** and the Gramophone.—F. C. Topham, p. 408.
Radiodiffusion (Radio-**broadcasting**).—E. Girardeau, p. 409.
Les Lignes Électriques en Cables à 132,000 Volts de New York et de Chicago (132,000 volt **Cables**).—Emanueli, p. 591.
Cruise VII of the "**Carnegie,**" 1928–1931, p. 528.
Carrier-current Control for Street Lighting.—R. R. Cowles, p. 589.
Carrier Systems on Long-distance Telephone Lines.—Affel, Demarest and Green, p. 589.
Australian **Carrier** Systems.—R. N. Partington, p. 694.
Power Line **Carrier** Telephony.—L. F. Fuller and W. A. Tolson, p. 694.
Problems in Power-line **Carrier** Telephony.—W. B. Wolfe and J. D. Sarros, p. 694.
Appareils pour la Remise à L'Heure Automatique des Pendules par T.S.F. (**Clock**-setting, etc., by wireless).—M. Lavet, p. 409.
La Remise à l'Heure Automatique des Pendules par T.S.F. (**Clock**-setting by Wireless), p. 472.
Colour by Wire or Radio, p. 105.
Die Arbeiten des Ausschusses für Schaltsbilder des Verbandes deutscher Elektrotechniker (The work of the **Committee** for Circuit- and Wiring-diagrams of the V.D.E.).—W. Heym, p. 408.
Méfiez-vous des Chiffres Inscrits sur les Appareils (Distrust the figures inscribed on **Component** Parts).—J. Granier, p. 471.
Decreasing Radio **Congestion.**—R. D. Duncan, Jr., p. 349.
Conducteurs n'Obéissant pas à la Loi d'Ohm : Les Soupapes Électriques à Contact (Conductors which disobey Ohm's Law : electric **contact** rectifiers).—L. Dubar, p. 591.
The Theory of **Contact**-detectors : Investigations of Detector Contacts : More about the Crystal Detector Problem, p. 591.
Study of Imperfect Metallic **Contacts.**—Todesco and Rossi, p. 591.
T.S.F. et Géologie : La Dérive des Continents (Wireless and Geology : the Origin of **Continents**).—J. Vivié, p. 590.
Contractions for Titles of Periodicals.—R. L. Sheppard, p. 590.
Contractions for Titles of Periodicals.—Allan Gomme, p. 694.
The New Radio-Telegraph **Convention.**—Chetwode Crawley, p. 231.
Co-operation Between the Institute of Radio Engineers and Manufacturers' Associations.—A. N. Goldsmith, p. 650.
The Influence of Various Gases upon Wire Vibration in a **Corona** Discharge Tube.—Snyder and Evans, p. 470.
Experiments on the Space Charge Around a Conductor emitting **Corona.**—Carrol and Lusignan, p. 591.
Analogy between the **Crystal** Detector and a Vacuum Tube.—W Ogawa, p. 527.
The Effect of Chemical Composition on the Sensitivity of Galena as a Radiodetector : and the Cold Emission from **Crystals.**—W. Ogawa, C. Nemoto and S. Kaneko, p. 693.
Projection of **Curves** corresponding to Variable Currents.—A. Bartorelli, p. 589.
Some Fundamental **Definitions.**—R. A. Wilmotte, p. 695.
Mitteilung zum Detektorproblem : der Elektrolytische Detektor (The **Detector** Problem : the electrolytic detector).—G. G. Reissaus, p. 695.
High Frequency Sound Radiation from a **Diaphragm.**—R. B. Lindsay, p. 694.
Über ein optische Interferenzmethode zur Untersuchung von Membranen (An optical interference method of investigating **diaphragms**).—P. Paasche, p. 695.
Studien über Schwingungen von Kreisplatten und Ringen (The Vibrations of **Discs** and Rings).—W. Hort and M. Koenig, p. 693.
Fernablesung von Zeigerstellungen Mittels Hochfrequenz (**Distant-reading** of Meters, etc., by H.F. Method).—Hollmann and Schultes, p. 471.
The **Disturbance** of Radiocommunication by Tramways and its Remedies.—Clausing and Muller, p. 410.
Versuche zur Erklärung der Staubelectrisierung (Experiments for the Elucidation of **Dust**-electrification).—H. Israel, p. 589.
Dynamo Unipolaire Poirson, p. 410.
Differential Intensity Sensibility of the **Ear** for Pure Tones.—R. R. Riesz, p. 529.
Aus der Grossen Deutschen Funkausstellung (From the great German Radio **Exhibition**).—W. Burstyn, p. 695.
Die Berliner Funkschau, 1928 (The Berlin Radio **Exhibition,** 1928).—H. Kröncke, p. 694.
Über Elektrischer Felder in der Umgebung Lebender Wesen (On Electric **Fields** in the Neighbourhood of Living Beings).—F. Sauerbruch and W. Schumann, p. 349.
Über Elektrische Felder Physiologischen Ursprungs (Electrical **Fields** of Physiological Origin).—W. O. Schumann, p. 649.
Über Elektrische Felder in der Umgebung Lebender Wesen (Electrical **Fields** in the Neighbourhood of Living Beings).—M. v. Ardenne, p. 590.
Frequenzvervielfachung Durch Eisenwandler (**Frequency** multiplication by iron frequency transformers)—Part I.—E. Kramar, p. 590.
Frequenzvervielfachung Durch Eisenwandler (**Frequency** multiplication by iron frequency transformers).—Final Parts.—E. Kramar, p. 650.
Sur l'Emploi du Démultiplicateur de Fréquence Ferromagnétique comme Multiplicateur de Phases (The use of the ferromagnetic **frequency** transformer as a phase multiplier).—E. Rouelle, p. 590.
Machines à Courant Continu avec ou sans Collecteur (D.C. **generators** with or without commutators), p. 472.
Geophysical Methods of Locating Minerals, p. 471.
Geophysical Methods of Prospecting.—Eve and Keys, p. 528.
Use of Megger Circuit in **Geophysical** Prospecting, p. 694.
Les Reproducteurs Électriques de Phonographie (Electric "Pick-Ups" for **gramophones**, etc.)—A. Cremailh, p. 410.
Harmonic Production in Ferromagnetic Materials at Low Frequencies and Low Flux Densities.—E. Peterson, p. 693.
The **Heaviside** Operator and the Operational Calculus.—W. A. Barclay, p. 650.
Une nouvelle Application des Courants de Haute Frequence (A new application of **H.F. Currents**).—.—Bordier, p. 694.
Radio—An Aid to **Improving** Service.—L. Beckwith, p. 40.
On the Computation of **Induced Voltage** in a Communication Line caused by occasional Grounding of a neighbouring Power Line.—K. Kanaya, p. 695.
Über die Induktionswirkung von Starkströmen auf Benachbarte Leitungen (The **induction** effect of power currents on neighbouring conductors).—H. Schiller, p. 589.
Chauffage par Induction (Heating by **Induction**).—P. Bunet p. 695.

Transmission of **Information.**—R. V. L. Hartley, **p. 589.**
Joint Meeting of the **Institution** of Electrical Engineers and the American Institute of Electrical Engineers, **p. 410.**
Interference Elimination, **p. 590.**
Les Symboles Graphiques Internationaux Concernant l'Électrotechnique (The **international** graphic symbols relating to electrical engineering), **p. 591.**
The **International** Union of Scientific Radiotelegraphy.—J. H. Dellinger, **p. 650.**
The **International** Radiotelegraph Conference of Washington, 1927.—W. D. Terrell, **p. 349.**
Über die Vorgänge am System Halbleiter-Leiter (The processes in the "Semi-conductor-Conductor" **-Johnsen-Rahbek-**system).—H. Toby, **p. 591.**
League of Nations, **p. 40.**
Die Radiotechnik auf der Leipziger Frühajahrsmesse, 1928 (Radio technics at the **Leipsic** Spring Fair, 1928), **p. 528.**
Télégraphie Optique à écoulement rapide des Signaux (**Light-ray** Telegraphy, high-speed).—F. Fournier, **p. 409.**
Das Problem der Photo-telephonie (The Problem of Telephony by **Light-Rays**).—K. Zickler, **p. 695.**
Luminous Pressure Waves, **p. 591.**
Ein einfaches Verfahren zum Magnetisieren von Permanenten Magneten (A simple method of **magnetising** permanent magnets).—E. Schulze, **p. 527.**
The Cable Wireless **Merger.**—F. J. Brown, **p. 349.**
The **Movietone.**—W. I. G. Page, **p. 105.**
The **National Physical Laboratory,** Teddington: Inspection by the General Board, **p. 591.**
Marine et T.S.F. (The **Navies** and "Wireless").—Major X., **p. 409.**
Radio Applied to **Petroleum** Prospecting.—G. R. Chinski, **p. 471.**
Quelques Procédés d'Amplification des Courants Photo-Electriques et Applications à l'Emission des Bélinogrammes (Some methods of amplifying **photo-electric** currents with application to the transmission of "Belinogrammes").—M. P. Toulon, **p. 291.**
Phototelegraphy, p. 291.
Pictures by Wireless.—A. J. Smith, **p. 230.**
Über Verstärkung in der Bildtelegraphie (On amplification in **picture** telegraphy).—O. Schriever, **p. 231.**
Die neuesten Fortschritte des Bildtelegraphie-Systems Telefunken-Karolus-Siemens (The latest progress of the **Picture-**telegraphy-system Telefunken-Karolus-Siemens).—F. Schröter, **p. 410.**
Versuche Mit Photozellen für Bildfunkzwecke (Experiments with Photo-cells for **Picture-**Wireless purposes).—W. Nestel, **p. 471.**
Picture Reception (Recent Important Developments in Home-reception Process, **p. 472.**
The "Fultograph": First Complete Description of the **Picture** Receiving Machine.—F. H. Haynes, **p. 693.**
La nouvelle méthode Lorenz-korn pour la transmission des Images par la T.S.F. (The new Lorenz-Korn method of **picture** telegraphy by Wireless), **p. 694.**
Picture Telegraphy, **p. 694.**
Über Piezoquarzplatten als Sender und Empfänger Hochfrequenter Akustischer Schwingungen (**Piezo-quartz** plates as sender and receiver of H.F. acoustic oscillations).—F. W. Hehlgans, **p. 591.**
Radio Acoustic **Position** Finding in Hydrography.—J. H. Service, **p. 649.**
The Possible Application of High-Frequency **Power** to Electric Traction.—W. Cramp, **p. 649.**
Electrical **Prospecting.**—J. J. Jakosky, **p. 648.**
Radio Vision.—C. Francis Jenkins, **p. 39.**
What Do They Know of **Radio** . . . ?—D'Orsay Bell, **p. 694.**
A **Rectifier** for High Tension Electricity, **p. 472.**
Kommission für Hochfrequenztechnik: **Regulations** for Electric Sound-apparatus such as Loud Speakers, Head-telephones, etc., **p. 649.**
A Galvanometric **Relay** Without Contacts, **p. 471.**
Fernsteurung durch Tonfrequenz (**Remote control** by means of note frequency).—F. J. Dommerque, **p. 349.**
Il Fonografo e la Riproduzione Elettrica (The phonograph and electric **reproduction**).—U. Guerra, **p. 231.**
High Angular Velocities obtained by **Rotors** having no Solid Axis.—E. Henriot and E. Nuguenard, **p. 694.**
VI Kongress der Assoziation der russischen Physiker (VI Congress of the Assoc. of **Russian** Physicists).—M. Born, **p. 694.**
At the **Science Museum:** Some Recent Additions to the Radio Section.—R. P. G. Denman, **p. 529.**
Some Experiments on the Light-sensitivity of Commercial **Selenium** Cells.—G. P. Barnard, **p. 650.**
The **Series Capacitor:** Construction and Operation of New Equipment designed to increase Load-carrying Capacity of Line and to improve Voltage Regulation, **p. 650.**
Some New Applications of **Short** Radio Waves.—J. Taylor and W. Taylor, **p. 650.**
Drahtlose Rangierbefehlsübermittlung (Wireless **shunting-control** at goods stations).—K. Steinner, **p. 408.**
The Measurement of **Sound-**absorption in a Room.—V. O. Knudsen, **p. 472.**
Zur Messung von Nachhalldauer und Schall-absorption (The Measurement of Echo-duration and **Sound-absorption**).—Meyer and Just, **p. 649.**
Eine neue Methode der Klanganalyse (A new method of **sound** analysis).—M. Grützmacher, **p. 168.**
Ein registrievender Schallmesser und seine Anwendungen (A recording **sound-meter** and its applications).—E. Gerlach, **p. 168.**
Sound-proof Rooms, Bell Telephone Laboratories, **p. 590.**
Les Ondes ultrasonores (**Sound** waves of ultra-audible frequency).—P. Langevin, **p. 409.**
Personal and Impersonal **Styles** in Scientific Communications.—N. R. Campbell, **p. 529.**
Les Ondes Courtes et la Télégraphie sans Fil Souterrain (Short waves and **subterranean** telegraphy).—J. M. Sacazes, **p. 409.**
Émission et Réception par un Récepteur à super-réaction (Transmission and reception by a **super-regenerative** receiver).—G. Beauvais, **p. 528.**
Surge-voltage Investigations, **p. 650.**
Talking and Synchronised Motion Pictures.—W. H. Bristol, **p. 230.**
Die Einphasenkoppelung, Ein Mittel zur Erhöhung der Betriebsicherheit der Hochfrequenz Telephonie auf Leitungen? (Single-phase coupling, a method of increasing the reliability of high-frequency **telephony** along power lines?).—Dressler and Tätz, **p. 589.**
Sférographe: Appareil téléphotographique de la Société Française Radioélectrique (Sferograph: a **telephotographic** apparatus of the S.F.R.).—Chauveau, **p. 649.**
Le "**Teletype.**"—Bonnin, **p. 649.**
Television.—H. E. Ives, **p. 39.**
European Progress in **Television.**—W. J. Brittain, **p. 529.**
Bildübertragung und Fernsehen (Picture Telegraphy and **Television**).—R. Hiecke, **p. 649.**
Television by Cathode Rays.—A. A. Campbell Swinton, **p. 528.**
The Use of a Moving Beam of Light to Scan a Scene for **Television.**—F. Gray, **p. 410.**
Un Nouveau Système de Télévision et de Télécinematographie (A new system of **Television** and Telekinematography).—L. Thurm, **p. 529.**
Bildfunk und Fernsehen auf der 5 Deutschen Funkschau (Picture Wireless and **Television** at the 5th German Radio Exhibition).—H. Kröncke, **p. 694.**
The Production and Utilisation of **Television** Signals.—F. Gray, J. Horton and R. Mathes, **p. 39.**
Synchronisation of **Television.**—H. M. Stoller and E. R. Morton, **p. 39.**
Radio Transmission System for **Television.**—E. L. Nelson, **p. 39.**
United States: **Television, p. 169.**
La Télévision Electrique (Electric **television**).—A. Dauvillier, **p. 291.**
Sur l'Utilisation de l'Énergie Thermique des Mers (The Utilisation of the **thermal** energy of seas).—Claude and Boucherot, **p. 471.**
Les Stations de Signaux Horaires (**Time-Signal** Stations).—De la Forge, **pp. 410, 471 and 590.**
Sur L'Unification des Signaux Horaires Radiotélégraphiques (The Unification of **Time Signals**).—G. Bigourdan, **p. 649.**
British **Time Signals** from Rugby, GBR, **p. 105.**
Radio Communication on Moving **Trains, p. 590.**
Die Zugbeeinflussungsysteme bei den Eisenbahngesellschaften der V.S. Amerika (**Train-**control systems on the U.S.A. Railways).—A. Kammerer, **p. 590.**
Das Induktive Zugbeeinflussungsystem mit Gleichstromerregung (Inductive **train-**control with direct-current).—O. Schirm **p. 649.**
Réceptions Radiotéléphoniques sur Trains en Marche (The reception of radio telephony on moving **trains**).—R. Saglio, **p. 168.**
Signalübertragung auf fahrende Züge mittels Wechselstrominduktion und Resonanz (Signal communication on moving **trains** by means of alternating current induction and resonance).—P. Tätz, **p. 169.**
Les Ondes Courtes et les Traversées Transatlantiques (Short Waves and **Transatlantic** Flights), **p. 409.**
The "**Ultramicrometer.**"—J. Obata, **p. 591.**
Enkele Physiche Beschouwingen over Ultra-Korte Golven, Mede in Verband met de Uitzendingen van het Philips' Radio-Laboratorium (Some physical considerations on **ultra-short** waves based on transmissions from the Philips' Radio Laboratory).—B. Van der Pol, **p. 410.**
Ultrasonics.—R. W. Boyle, **p. 591.**
Procédé D'Obtention du Maximum de Rayons Ultraviolets à Ondes Courtes (Method of obtaining the maximum short wave **Ultra-violet** Rays).—N. Iarotzky, **p. 650.**
Experiments in **Underground** Communication through Earth Strata.—Ilsley, Freeman and Zellers, **p. 694.**
Über eine Methode zur Ergeugung von Sehr Kurzen Elektrischen Wellen Mittels Hochfrequenzfunken (A method of generating **very short** electric waves by high-frequency spark).—E. Busse, **p. 408.**
An Instrument for Measuring **very small** Displacement or Motion and its various applications.—J. Obata, **p. 349.**
Some Experiments on **Water-divining.**—A. E. M. Geddes, **p. 650.**
Weighing by Radio, **p. 230.**
The Behaviour of Overhead Transmission Lines in High **Winds.**—E. H. Lamb, **p. 693.**
Le Grandes Heures de la T.S.F. (The great hours of "**Wireless**").—Major X——, **p. 409.**
—Scientific **Wiring.**—W. B. Medlam, **p. 349.**

EXPERIMENTAL
WIRELESS
& The WIRELESS ENGINEER

VOL. V. JANUARY, 1928. No. 52.

Editorial.

The Copper-Oxide Rectifier.

CONSIDERABLE interest was aroused at the National Radio Exhibition in the copper-oxide rectifier, or electronic rectifier, as it is called in the article by Grondahl and Geiger describing its construction and properties in the March number of the *Journal of the American Institute of Electrical Engineers*. The phenomenon upon which the rectifier is based was reported to the American Physical Society by Grondahl in April, 1926. It was found that if a layer of oxide was formed on a sheet of copper and contact made by a piece of lead pressed against the oxide, the resistance to current passing from the lead to the copper was less than that to current flowing in the other direction. This is shown in the characteristic curve reproduced in Fig. 1, in which it will be noted that the current scale in one direction is in amperes and in the other in milliamperes. The reverse current is very small, but the low resistance does not set in until about half a volt is applied. For an applied voltage of 4 or 5 volts the resistance in one direction is about 12,000 times that in the other. The efficiency of rectification is very poor for small currents but rises rapidly as the current is increased; the lower limit of the current for efficient rectification can be reduced by reducing the cross-section of the rectifier.

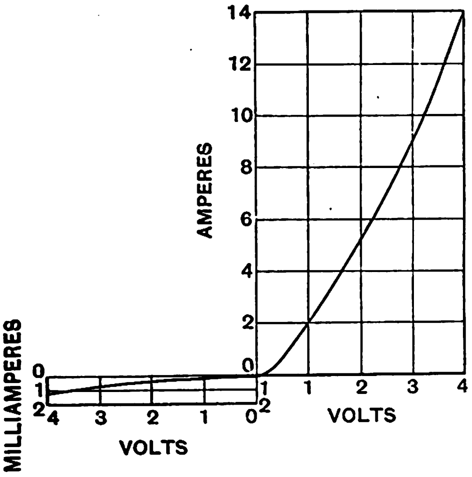


Fig. 1. *Characteristic curve of the rectifier.*

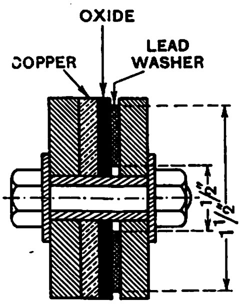
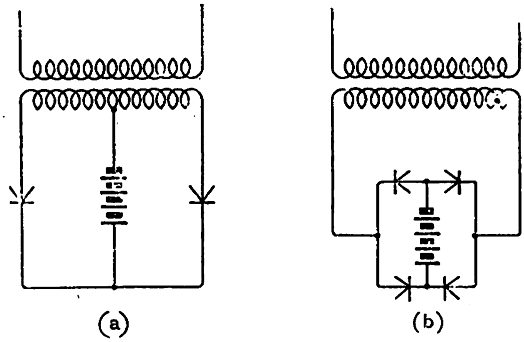


Fig. 2.
Method of clamping the electrodes of the rectifier.

In practice, the rectifier is built up in a very robust and simple form by threading the copper disc with oxidised face on a bolt and clamping a leaden ring against the oxide face by means of a nut with suitable insulating tubes and washers. Such a unit is shown in Fig. 2. Two of these can be used in conjunction with a tapped secondary transformer, as shown in Fig. 3 (a). Another arrangement is shown in Fig. 3 (b), the four rectifiers for which can be assembled as a single unit, as shown in Figs. 4 (a) and (b).



Figs. 3 (a) and (b). *Circuits showing how the units can be used in conjunction with transformers.*

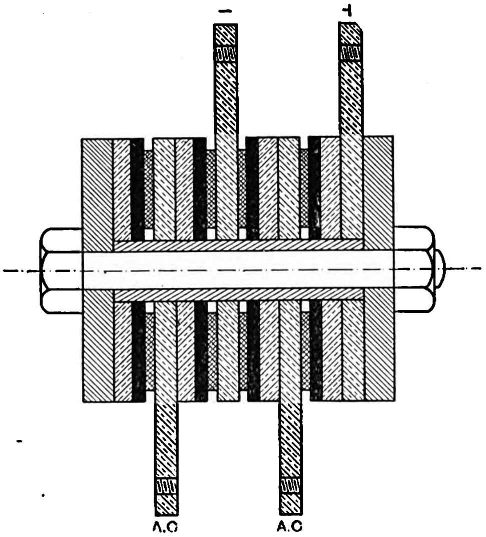


Fig. 4 (a). *Sectional drawing.*

The unit shown in Fig. 2 is suitable for about 6 volts and a current depending on the area of cross-section and the cooling facilities. If the current density exceeds 2 amperes per square inch forced ventilation or oil immersion is necessary. A unit with ventilating fins and immersed in oil can carry 3½ amperes per square inch.

If properly designed for the output required, efficiencies of 80 per cent. and over can be obtained but efficiencies between 50 and 70 per cent. are more common.

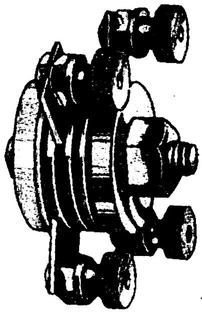


Fig. 4 (b).

Photograph of the unit shown in section in Fig. 4 (a).

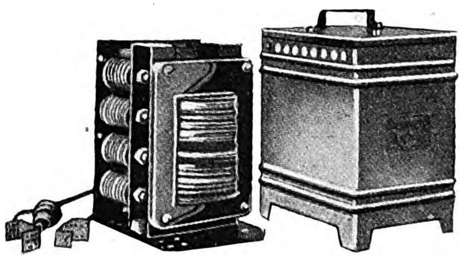


Fig. 5. *Battery charging unit removed from its case, showing the transformer mounted with it.*

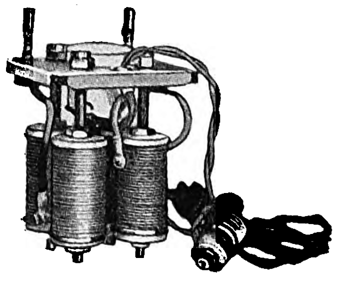


Fig. 6. *Columns of discs for a H.T. battery charger.*

No satisfactory explanation has been found for the rectifying action which appears to occur at the junction of the copper and the thin film of oxide which is usually only about 0.001 inch thick.

This type of rectifier has obvious advantages over other types in the absence of liquid to spill or evaporate, in the absence of moving parts to get out of order or of valves to burn out. It may be that the copper oxide rectifier has troubles of its own, however; if so we shall doubtless hear of them. It is being made for many purposes; Fig. 5 shows a 2-ampere, 6-volt battery charging unit in which the rectifying units can be seen on the side of the transformer; Fig. 6 shows the columns of discs constituting the rectifier for a H.T. battery charger.

The Stability of the Tuned-Grid Tuned-Plate H.F. Amplifier.

By R. T. Beatty, M.A., B.E., D.Sc.

HIGH-FREQUENCY reaction, the mainspring of the great majority of receiving sets, an agent which can exalt a whisper to loud-speaker level, which can conceal losses due to unworthy components and unskilled construction, and which can confer high selectivity on the flattest of resonance curves, is yet a quantity to which a numerical value can seldom be attached.

Otherwise the constituents which contribute to the total amplification are known tolerably well. The voltage gain due to a tuned grid circuit, the gain from grid to plate of a valve, the step-up of a transformer are confidently given in figures, but reaction, which is itself a gain exceeding any of these, remains vague.

The reason is simple enough. When a reaction coil is brought from the plate circuit to transfer energy to the grid coil, the transference depends on the mutual inductance between these two coils, which itself depends on the geometry of each coil and on their relative positions. *Mutual inductance is a quantity which the experimenter finds intolerably tedious to calculate and difficult to measure.*

But when tuned-grid tuned-plate circuits are used and reaction is due to capacity, either introduced between grid and plate or already existing there between the valve electrodes, the matter becomes much more simple. Such a capacity is not difficult to measure and is easy to guess and a numerical value for the extra gain due to reaction can readily be assigned. It is true that with three-electrode valves an unneutralised amplifier of this kind can be relied on to do one thing only, that is to oscillate continuously and mercilessly, but the advent of the shielded-plate valve, with its very low residual plate-grid capacity, has altered the situation completely and high frequency amplifiers can now be built with perfect stability and with reaction which is under control and calculable.*

1. Conductance is Preferable to Resistance.

At this point some readers will say: "These calculations are not as easy as you think: we have seen some before, and they have depressed our spirits considerably." Quite so, I have seen a formula for voltage amplification with capacity reaction which extended over several lines of a radio journal: it was stately and agonising.† But there is a rule for avoiding complicated formulæ and it is this:—

In the case of an amplifier with tuned circuits never allow a resistance to appear in a formula. Replace it by the corresponding conductance.

Conductance $= 1/\text{resistance}$ or $\sigma = 1/R$.

Further, when a series resistance appears in a tuned circuit replace it by a parallel conductance. Thus r in series with $L\omega$ is equivalent to a resistance $L^2\omega^2/r$ in parallel with $L\omega$ and this should be expressed as a conductance $\sigma = r/L^2\omega^2$.

Ohm's law will now appear in the form $i = e\sigma$ instead of the usual form $e = iR$.

2. A Typical Parallel Circuit.

This is shown in Fig. 1. An E.M.F. e is placed in parallel with a coil, condenser, and conductance. The current i is equal to the sum of the three currents flowing downwards through these three elements. Hence

$$i = e[\sigma + jC\omega - j/L\omega] \quad .. \quad (1)$$

In Fig. 1 σ is drawn horizontally and $C\omega - 1/L\omega$ vertically.

---

* A list of the symbols employed is given at the end of the article.

† But neither grateful nor comforting.

Then $\tan\theta = t = [C\omega - 1/L\omega]/\sigma$
and equation (1) becomes

$$i = e\cdot\sigma[1+jt] \quad .. \quad (2)$$

t is the tangent of the phase angle θ by which the current leads the E.M.F. When $t=0$ the circuit is tuned to the incoming frequency, the LC circuit forms a barrier of infinite impedance and there remains only a pure conductance σ so that $i = e\sigma$ as is evident from equation (2).

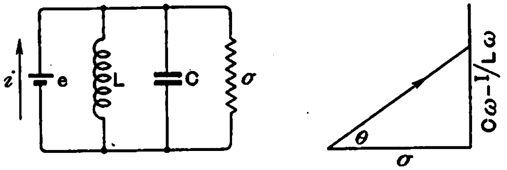


Fig. 1. *A typical parallel circuit.*

The coefficient of e in equation (1) is a vector operator and Fig. 1 shows that it is represented in magnitude and direction by the sloping side of the triangle. It is called the admittance of the circuit.

3. The Tuned-grid, Tuned-plate Circuit.

This is shown diagrammatically in Fig. 2, e is the high frequency signal voltage injected in series with the grid coil L_1, we suppose that it is produced by a loosely coupled untuned aerial coil; e_1 and e_2 are the alternating grid and plate voltages; the valve is represented by a generator of E.M.F. μe_1 where μ is the valve amplification factor, in series with a conductance σ_v, the reciprocal of the valve differential resistance. C_0 is the grid-plate valve capacity. The tuned grid circuit is $L_1C_g\sigma_1$; the tuned plate circuit is $L_2C_p\sigma_p$. As emphasised in section (2) parallel conductances are used instead of series resistances.

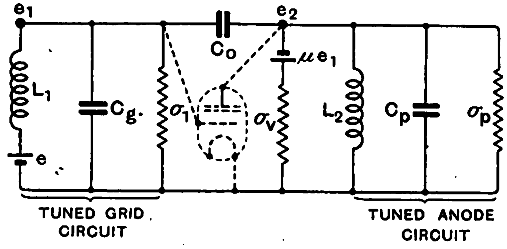


Fig. 2. *A high-frequency tuned-grid tuned-plate amplifier, showing ~ voltages. The valve is replaced by a generator of ~ E.M.F. μe₁ with series conductance σv.*

We will now derive a single expression giving the ratio of e_2 to e, that is the overall amplification produced by this single stage set. To do this we dissect Fig. 2 into two parts as in Figs. 3 and 4: each part will supply an equation connecting $e_1\cdot e_2$ and e and on eliminating e_1 from these two equations the ratio of e_2 to e will emerge as a fairly simple quantity.

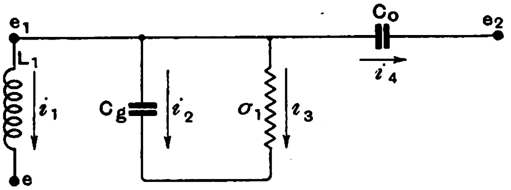


Fig. 3. *Component parts of Fig. 2.*

4. The Equations of the Amplifiers.

We know that in any circuit the sum of all the currents flowing away from any point must be zero. In Fig. 3 the sum of the currents flowing away from the point e_1 is $i_1+i_2+i_3+i_4=0$. Replacing each current by its corresponding P.D. multiplied by an admittance we get

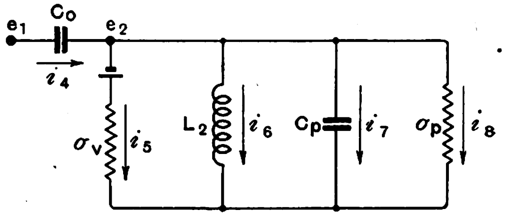


Fig. 4.

$$[e_1 - e]/j\cdot L_1\omega + e_1\cdot j\cdot C_g\omega + e_1\cdot\sigma_1 + \\ + [e_1 - e_2]j\cdot C_0\omega = 0 \quad (3)$$

which may be written

$$e_1[\sigma_1 + (C_g + C_0)j\omega - j/L_1\omega] - e_2\cdot j\cdot C_0\omega \\ = -e\cdot j/L_1\omega \quad (4)$$

Evidently C_g and C_0 can be lumped together: put $C_g + C_0 = C_1$, then the expression in square brackets is of the same form as that in equation (1) and so can be expressed as in equation (2).

Hence

$$e_1 \cdot \sigma_1[1+jt_1]-e_2 \cdot j \cdot C_0\omega = -e \cdot j/L_1\omega \quad (5)$$

where $t_1 = [C_1\omega - 1/L_1\omega]/\sigma_1$ .. (6)

Similarly in Fig. 4 the sum of all the currents flowing away from the point e_2 is

$$-i_4+i_5+i_6+i_7+i_8=0.$$

Replacing each of these by its corresponding P.D. multiplied by an admittance we get

$$-[e_1-e_2]j \cdot C_0\omega + [e_2+\mu e_1]\sigma_v + e_2 [1/j \cdot L_2\omega + j \cdot C_p\omega + \sigma_p] = 0 \quad (7)$$

which may be re-written as

$$e_2[\sigma_p + \sigma_v + (C_p + C_0)j\omega - j/L_2\omega] + e_1[\mu\sigma_v - j \cdot C_0\omega] = 0 \quad (8)$$

σ_p and σ_v can be lumped together, also C_p and C_0; put $\sigma_p + \sigma_v = \sigma_2$, $C_p + C_0 = C_2$. Then the coefficient of e_2 is of the same form as that in equation (1) and so can be expressed as in equation (2). Accordingly it may be written as $e_2 \cdot \sigma_2[1+jt_2]$.

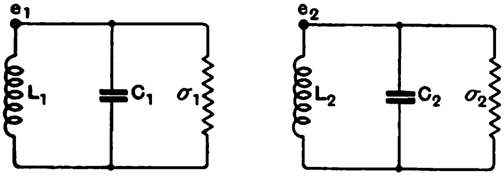


Fig. 5. *The equivalent grid and plate circuits.*

Again, considering the coefficient of e_1 in equation (8) $\mu\sigma_v$ is the mutual conductance g of the valve, while the term $C_0\omega$ is negligible compared with g.*

Hence when these substitutions are made equation (8) becomes

$$e_2 \cdot \sigma_2[1+jt_2] + e_1 \cdot g = 0 \quad .. \quad (9)$$

where $t_2 = [C_2\omega - 1/L_2\omega]/\sigma_2$ .. (10)

In equations (6) and (10) C_1 C_2 σ_2 are lumped quantities so that we are dealing with equivalent circuits (Fig. 5) which represent the grid and anode circuits somewhat modified. The inductances remain unaltered in Fig. 5, but each capacity has been slightly increased by the amount C_0 while the conductance of the plate circuit has been considerably increased by the addition of the valve differential conductance.

Equations (5) and (9) with their auxiliary equations (6) and (10) are the fundamental equations of the amplifier. They refer to two equivalent circuits shown in Fig. 5, from which the valve has disappeared. The mutual action between these two circuits is completely specified by equations (5) and (9). The tangents of the phase angles of the circuits are t_1 t_2.

6. The Overall Amplification.

Write down equations (5) and (9) together, *i.e.*,

$$e_1 \cdot \sigma_1[1+jt_1]-e_2 \cdot j \cdot C_0\omega = -e \cdot j/L_1\omega$$
$$e_1 \cdot g + e_2 \cdot \sigma_2[1+jt_2] = 0.$$

multiply the upper by g and the lower by $\sigma_1[1+jt_1]$ and subtract; e_1 will disappear and we have

$$e_2[\sigma_1\sigma_2(1+jt_1)(1+jt_2) + j \cdot g \cdot C_0\omega] = e \cdot j \cdot g/L_1\omega \quad .. \quad (11)$$

This may be written as

$$e_2/e = j \cdot A \cdot F \quad .. \quad .. \quad (13)$$

where $1/F = (1+jt_1)(1+jt_2)+j \cdot H$ .. (14)

$$H = g \cdot C_0\omega/\sigma_1\sigma_2 \quad .. \quad .. \quad (15)$$

$$A = g/L_1\omega \cdot \sigma_1\sigma_2 \quad .. \quad .. \quad (16)$$

A and H are numbers whose values are fixed by the constants of the circuits. F is a vector whose magnitude and direction are fixed partly by H, which depends only on circuit constants, and partly by t_1 and t_2 which depend on the tuning of the circuits due to moving the grid and plate condensers.

Equation (13) with its auxiliary equations (14, 15, 16) gives the overall amplification of the receiver shown in Fig. 2, expressed as a vector operator. It will be shown in the following sections that A is the amplification which would exist if back coupling were absent and the circuits tuned to the incoming signal, while F is the extra gain due to reaction. It will also appear that F and H can be represented on a parabola, from which the gain due to reaction can be read off by inspection.

---

* Thus taking

$C_0 = 1\mu\mu\text{F}$, $\omega = 10^7$, $g = 10^{-3}$ amps./volt.,

we have $C_0\omega = 10^{-12} \times 10^7 = 10^{-5}$ which is only 1 per cent. of g.

7. The Geometrical Meaning of F.

The expression $(1+jt_1)\,(1+jt_2)+j\cdot H$ which occurs in equation (14) can be put on a diagram as follows: $1+jt_1$ is the vector ST (Fig. 6) obtained by rotating a unit vector SV in an anti-clockwise direction through an angle θ_1 where $t_1 = \tan\theta_1$ and producing it till it meets the vertical line VT.

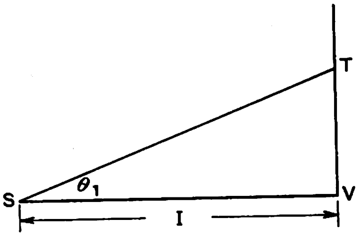


Fig. 6.

The next step is to multiply this vector ST by $1+jt_2$. This is done (Fig. 7) by rotating ST through an angle θ_2 ($t_2 = \tan\theta_2$), and producing it till it meets TR, the line drawn from T at right angles to ST. Hence SR represents $(1+jt_1)\,(1+jt_2)$. jH is a vertical vector PS (Fig. 8).

Accordingly $(1+jt_1)\,(1+jt_2)+j\cdot H$ is the vector sum of PS and SR, *i.e.*, PR. Hence $1/F$ is the vector PR.

Now, considering Fig. 8 more closely, we see that while H is fixed by the circuit constants, as equation (15) shows, SR depends on the values of t_1 and t_2: that is on the settings of the grid and plate equivalent condensers. If t_1 is fixed, then as t_2 is varied R will move along the line TR; if t_1 is varied the line TR itself will assume different positions as shown in Fig. 9.

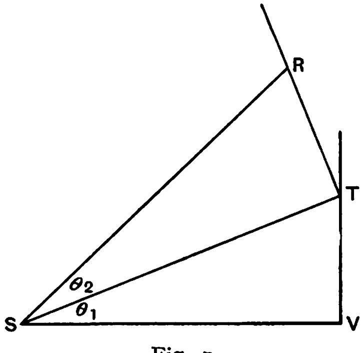


Fig. 7.

So when we try to draw the vector PR we find that although one end P is fixed and definite the other end R may lie on any one of a maze of lines T_1R_1 T_2R_2, etc., according to the settings of the tuning condensers.

The situation now seems desperate till we recollect that this maze of lines has an important property: every line touches a fixed parabola whose focus is at S and which is shown in Fig. 9, so that the point R, though it may lie *outside* or *on* the parabola, can never get *inside*.

We are only concerned with setting the tuning condensers to make F as *large* as possible, or, since the vector PR equals $1/F$, to make PR as *small* as possible. Accordingly R should lie on the parabola in any case, and should be pushed along the parabola till it gets as close as it can to P. It is evident that we could get closer by using the other half of the parabola, as in Fig. 10, that is the phase angles θ_1 and θ_2 should both be negative and hence from equations (6) and (10) the tuned circuits should be on the inductive side of resonance—the condenser values should be smaller than the resonance values.

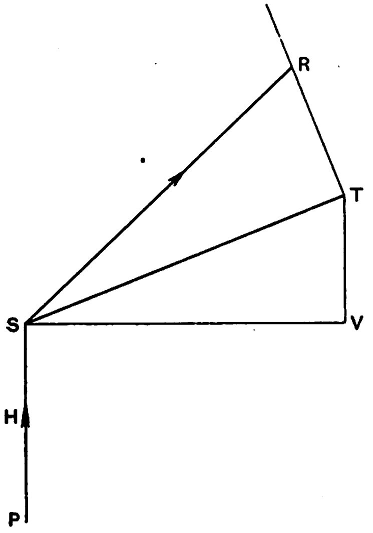


Fig. 8.

PR is smallest when it is the normal from P to the parabola. This smallest value of $1/F$ will be called $1/F_0$.

8. The Geometrical Meaning of H and F_0.

When the constants of the circuits are given so that H and A may be calculated from equations (15) and (16) the maximum gain F_0 due to reaction is found as follows: In the parabola $y^2=4x$ (Fig. 10) draw a vertical line PS to the focus equal to H and from P draw the normal PR. Then $F_0=1/PR$.

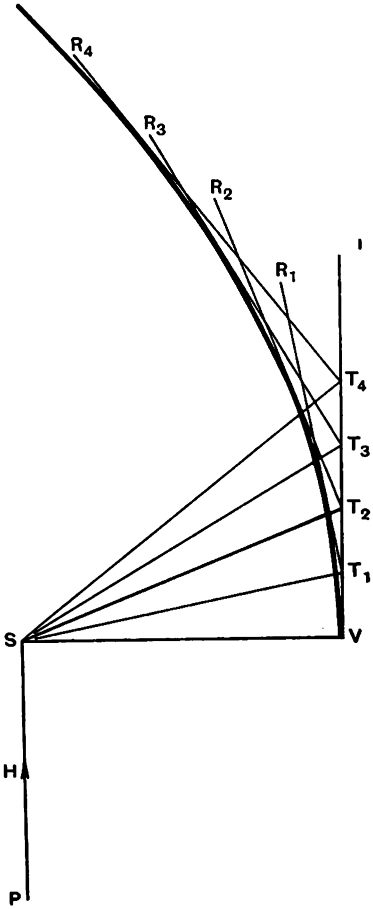


Fig. 9.

When no feedback exists, *i.e.*, when C_0 is zero, H is zero (equation 15), so that the point P coincides with S (Fig. 10). The normal from S is the line SV and its length is unity, so that $F_0=1$ and the phase angles θ_1 and θ_2 are zero. That is the tuning condensers should be set for resonance in this case. Also since $F_0=1$ the overall amplification (equation 13) is A.

A is the maximum amplification which can be obtained without the help of reaction. Its value is given by equation (16). F_0 is the extra gain due to reaction. Its value is found by the geometrical construction of Fig. 10. The overall amplification has the arithmetical value AF_0.

9. A Numerical Example.

Let the incoming signal be of frequency 2,070 kilocycles and assume that in Fig. 2 the grid and plate circuits are identical, with the values $\sigma_g=\sigma_p=3.2\times10^{-5}$ mhos* and $L_1\omega=L_2\omega=1{,}000$ ohms. The constants of the valve are taken as $g=8\times10^{-4}$ amps/volt. $\sigma_v=8\times10^{-6}$ mhos. $C_0=0.1\mu\mu$F: we are using a shielded plate valve which accounts for the low value of C_0.

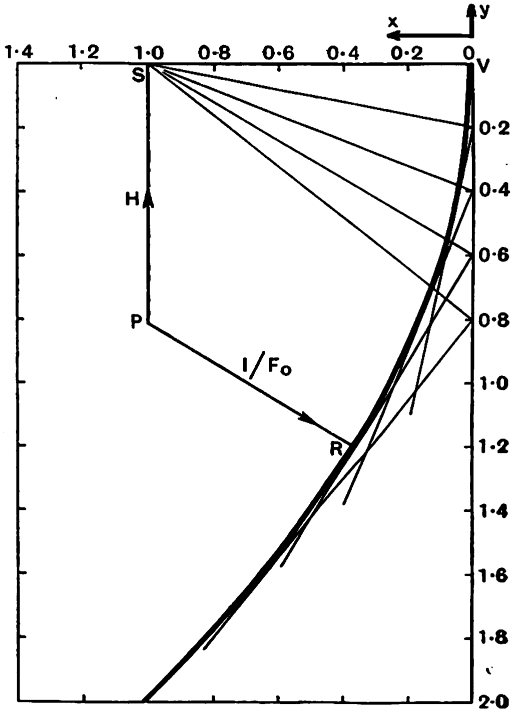


Fig. 10. *By means of a parabola* F_0 *can be found when* H *has been calculated.*

---

[*] If the shunt conductance in each tuned circuit in Fig. 2 is actually due to a resistance r in series with the coil then $\sigma=r/L^2\omega^2$ (see section 2). If $r=32$ ohms, $\sigma_g=\sigma_p=32/10^6=3.2\times10^{-5}$ mhos.

The tabulated values are

$$\omega = 2\pi \times 2.07 \times 10^6 \text{ radians/sec.}$$
$$\sigma_1 = 3.2 \times 10^{-5} \text{ mhos.}$$
$$\sigma_2 = \sigma_p + \sigma_v = 4 \times 10^{-5} \text{ mhos.}$$
$$g = 8 \times 10^{-4} \text{ amps/volt.}$$
$$C_0 = 10^{-13} \text{ farad.}$$
$$L_1\omega = 1{,}000 \text{ ohms.}$$

Equation (15) gives

$$H = \frac{8 \times 10^{-4} \times 10^{-13} \times 2\pi \times 2.07 \times 10^6}{3.2 \times 4 \times 10^{-10}} = 0.816.$$

making $H=0.816$ on the parabola in Fig. 10, and drawing the corresponding normal, we find

$$F_0 = 1/\text{length of normal} = 1.31.$$

From equation (16)

$$A = 8 \times 10^{-4}/10^3 \times 3.2 \times 4 \times 10^{-10} = 625.$$

Hence the overall amplification AF_0 is $625 \times 1.31 = 819$.

9. The Threshold of Instability.

As H increases, PR diminishes (Fig. 10) and as H approaches 2, PR approaches zero and therefore F_0 approaches infinity. When P has travelled downwards till it lies on the parabola the amplifier is on the threshold of instability, and for values of H greater than 2, self-oscillation will occur. Thus, in the numerical example just given, if C_0 were 0.3$\mu\mu$F instead of 0.1$\mu\mu$F, H would be equal to 2.4 and instability would result. Stability could be regained by reducing g to about one-third its value by dimming the filament or by increasing the shunt conductance of the grid and anode circuits to make $\sigma_g = \sigma_p = 5.5 \times 10^{-5}$ mhos. The reader can easily verify these results for himself.

10. The Voltage Gain from Grid to Plate without Reaction (stage gain).

The gain A from injected signal to plate may be split up into two parts, the gain from signal to grid and the gain from grid to plate. Equation (9) shows that this latter gain e_2/e_1 is equal to $g/\sigma_2[1+jt_2]$ which has its maximum value g/σ_2 when the plate condenser is set at resonance. In the numerical example given above, the gain from grid to plate is $8 \times 10^{-4}/4 \times 10^{-5} = 20$.

From the value for A given by equation (16) it is evident that since g/σ_2 represents the gain from grid to plate, the gain from signal to grid must be $1/L_1\omega \cdot \sigma_1$ or (if the resistance is r in series with $L_1\omega$) the more familiar expression $L_1\omega/r$.

In the example, where $L_1 = 1{,}000$ ohms, $r = 32$ ohms, the gain $= 1{,}000/32 = 31.25$ and hence $A = 31.25 \times 20 = 625$ as given above.

The overall amplification AF_0 can be divided into three parts. (1) The gain from injected signal to grid $1/L_1\omega.\sigma_1$ or $L_1\omega/r$; (2) the gain from grid to plate g/σ_2, (3) the gain F_0 due to reaction calculated from equation (15) and the construction shown in Fig. 10.

11. How to find F_0 when the Stage Gain is Specified.

We are now in a position to answer an important question. *What gain due to reaction do we get at any particular frequency when the stage gain e_2/e_1 is specified?* For example, if, as in section (11), the stage gain is 20, how do we find the value of F_0?

Equation (15) gives $H = g \cdot C_0\omega/\sigma_1\sigma_2$. Let us call the stage gain G then as in section (11) $G = g/\sigma_2$ so that we can eliminate σ_2 by replacing it by g/G. Again, as in the example in section (9) $\sigma_2 = \sigma_1 + \sigma_v = g/G$, so that σ_1 can be replaced by $g/G - \sigma_v$.

Hence
$$H = \frac{G \cdot C_0\omega}{\dfrac{g}{G} - \sigma_v} \quad .. \quad (17)$$

Equation (17) gives H when G the stage gain and ω are specified. F_0 can then be read off from Fig. 10. The reader may work out a numerical example using the data given in section (9). $G=20$ from this data and H will prove to be 0.816, leading to $F_0 = 1.31$.

12. Curves of Constant Reaction for the Standard Valve.

Equation (17) enables us to plot curves of constant F_0 on a logarithmic diagram where the abscissa is frequency and the ordinate is the stage gain. It is convenient to plot the frequency k in megacycles (millions of cycles): that is, we put

$$\omega = k\Omega \quad .. \quad .. \quad (18)$$

where $\Omega = 2\pi \times 10^6$

If now we rearrange equation (17) for ease in calculation and replace ω by $k\Omega$ we get

$$k/H = g[1 - G \cdot \sigma_v/g]/G \cdot C_0 \cdot \Omega \quad ... \quad (19)$$

With the valve which is taken as standard and whose constants are given in the list of symbols at the end of this paper, this becomes

$$k/H = 1.27\times 10^3[1-G/100]/G^2 \quad \ldots \quad (20)$$

Equation (20) gives the relation between G, the stage gain, and k, the frequency in megacycles, for any fixed value of H. In Fig. 11 two curves of constant reaction are plotted one for $H=2$ (F_0=infinity) and one for $H=.625$ ($F_0=1.2$). These curves refer to the valve which is taken as standard in this paper.

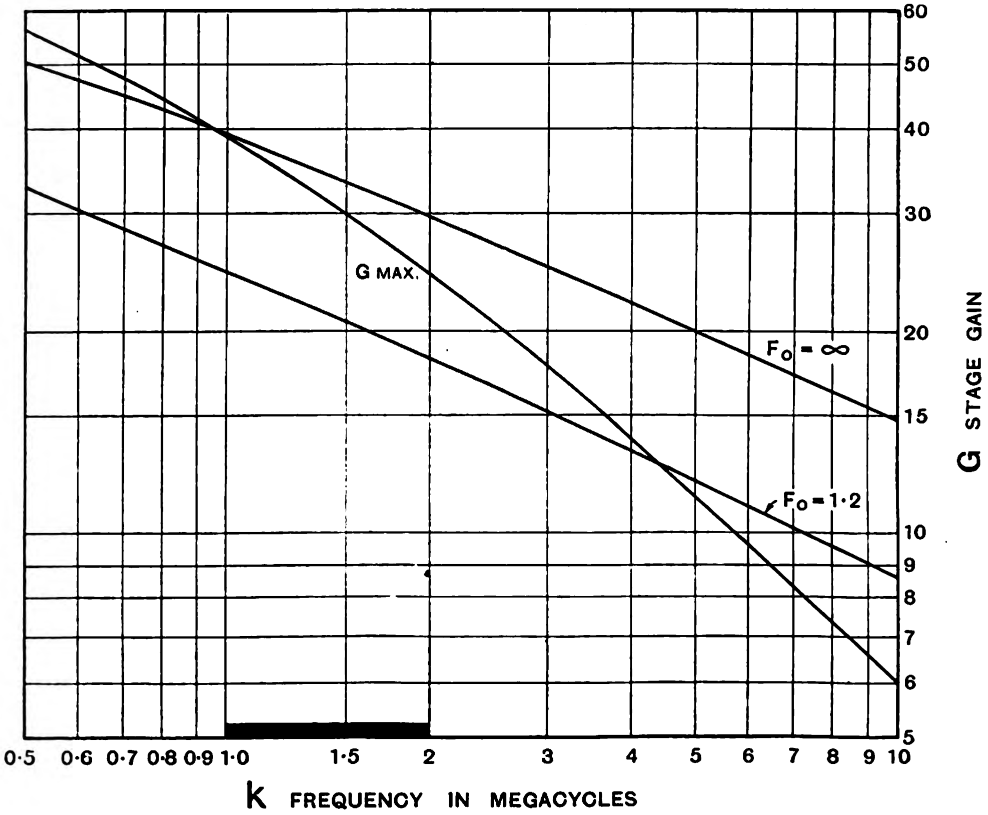


Fig. 11.

13. Curves of Constant Reaction for any Valve.

Fig. 11 would be enormously more useful if the curves could be easily altered to suit *any* valve, whether of the 3-electrode or the shielded-plate type, and we will now show how this can be done. All that is necessary is to make a slight re-arrangement in equation (19) as follows:—

$$[k/H]\,[C_0\cdot\Omega\cdot g/\sigma_v^2] = [1-G\cdot\sigma_v/g]\,g/G\cdot\sigma_v \quad (21)$$

Observe that on the right-hand side $G\sigma_v$ and g only occur as the quantity $G\cdot\sigma_v/g$ so that if, for example, g and G are each doubled the right-hand side will be unchanged. Similarly, if on the left-hand side g is doubled and k is halved no change will be produced. Accordingly, if we take the point $k=2$, $G=30$ in Fig. 11 and then replace the valve used by one whose mutual conductance is twice as great, the point will shift to one where $k=1$ $G=60$.

Now, on a logarithmic diagram an ordinate is doubled by raising the point by an amount equal to the distance from 1 to 2 (or the equal distance 10 to 20). Similarly an abscissa is halved by displacing the point to the left by an amount equal to the distance from 1 to 0.5 (or the equal distance 10 to 5). Thus every point on the curve $F_0=\infty$ must be raised an amount equal to the length of the bar shown at the bottom of Fig. 11 and simultaneously moved to the left by an equal amount. That is, as shown in Fig. 12, the curve must be displaced to the north-west by the amount shown by the arrow g. Again, if σ_v is doubled equation (21) shows that the right-hand side will be unaltered if G is halved, the left-hand side if k is increased four times. Thus the curve must be shifted as shown by arrow σ_v (Fig. 12). All possible shifts are shown in Table I.

TABLE I.

Change from standard valve where $g=8\times 10^{-4}$ amps/volt $\sigma_v=8\times 10^{-6}$ mhos $C_0=0.1\mu\mu\text{F}$	Factors by which k and G must be multiplied.	
	k	G
g doubled	$\frac{1}{2}$	2
σ_v doubled	4	$\frac{1}{2}$
C_0 doubled	$\frac{1}{2}$	1
H doubled	2	1

Fig. 11 does not extend far enough since if at $k=10$ megacycles we wish to move a curve to the left there will be no curve left at this point. Accordingly Fig. 13 has been drawn giving a greater range of k and G.

Further, since we are not interested in H so much as in F_0 a scale of F_0 has been drawn below Fig. 13. To pass from the curve $F_0=\infty$ to, say, $F_0=2$, displace the former curve to the left by an amount equal to the distance between ∞ and 2 on this scale.

Fig. 13 shows the curves of constant reaction for the valve whose constants are given in Table I. For any other valve slide the curve in question parallel to itself according to the rules given in Table I and indicated in Fig. 12. To pass from any F_0 curve to any other use the F_0 scale below Fig. 13.

Discussion of Curves of Constant Reaction.

Let us consider a valve in which the designer has succeeded in reducing C_0 to $.01\mu\mu$F. From Table I or Fig. 12 we see that since C_0 is diminished 10 times k must be increased 10 times; each F_0 curve must slide to the right over a distance equal to the interval from $k=1$ to $k=10$. This can be easily done by placing tracing paper on Fig. 13 and marking the point $k=1$ $G=10$. Then slide the paper to the *left* till the mark is on $k=0.1$; draw the curve $F_0=\infty$ and slide the tracing back to its original position; it will be found that the new threshold curve is almost clear of the diagram so that the set would remain stable even if $G_{max.}$ could be raised to 50 at frequencies up to $k=5$.

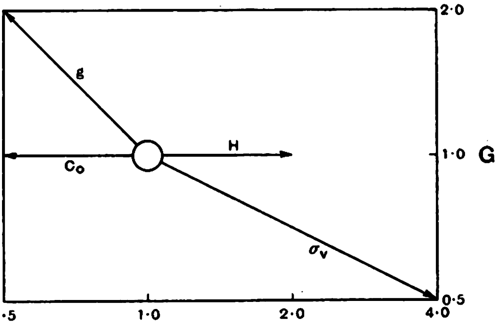


Fig. 12. *Shift of curves of constant reaction when any constant is doubled.*

Again, suppose g σ_v and C_0 each trebled: we must multiply k in succession by 1/3, 9, and 1/3, while the multipliers for G are 3, 1/3, and 1. The result is that k and G are unchanged, no shift of the F_0 curves results. Fig. 12 shows the same thing: each vector must be increased by 50 per cent. and the vector sum of the three adds up to zero showing that no displacement of the curve is to be made.

15. Practical Limitations to the Stage Gain G.

The maximum possible stage gain is determined by the maximum plate load which can be built up: at resonance this is a pure resistance of magnitude $L^2\omega^2/r$. For any given coil in a given copper screen box, the ratio $L\omega/r$ remains fairly constant at different frequencies, the increase in the H.F. resistance r keeping pace with the increase in ω, and may have some value from 50 to 100 according to the coil and screen used. Since the coil possesses self-capacity its $L\omega$ cannot be made greater than that which will make it resonate at the desired frequency without any condenser, but we cannot attain this value in practice on account of the difficulty which would be found in tuning. Thus, if the stray capacity is 5μμF and at 1,000 kilocycles we wish to tune to a station 10 kilocycles away we must add a capacity of only 0.1μμF. *Such a razor-edged set would be impossible to work.* Accordingly we must add ballast capacity for the sake of uniform and easy tuning. In constructing a set to deal with the *total*

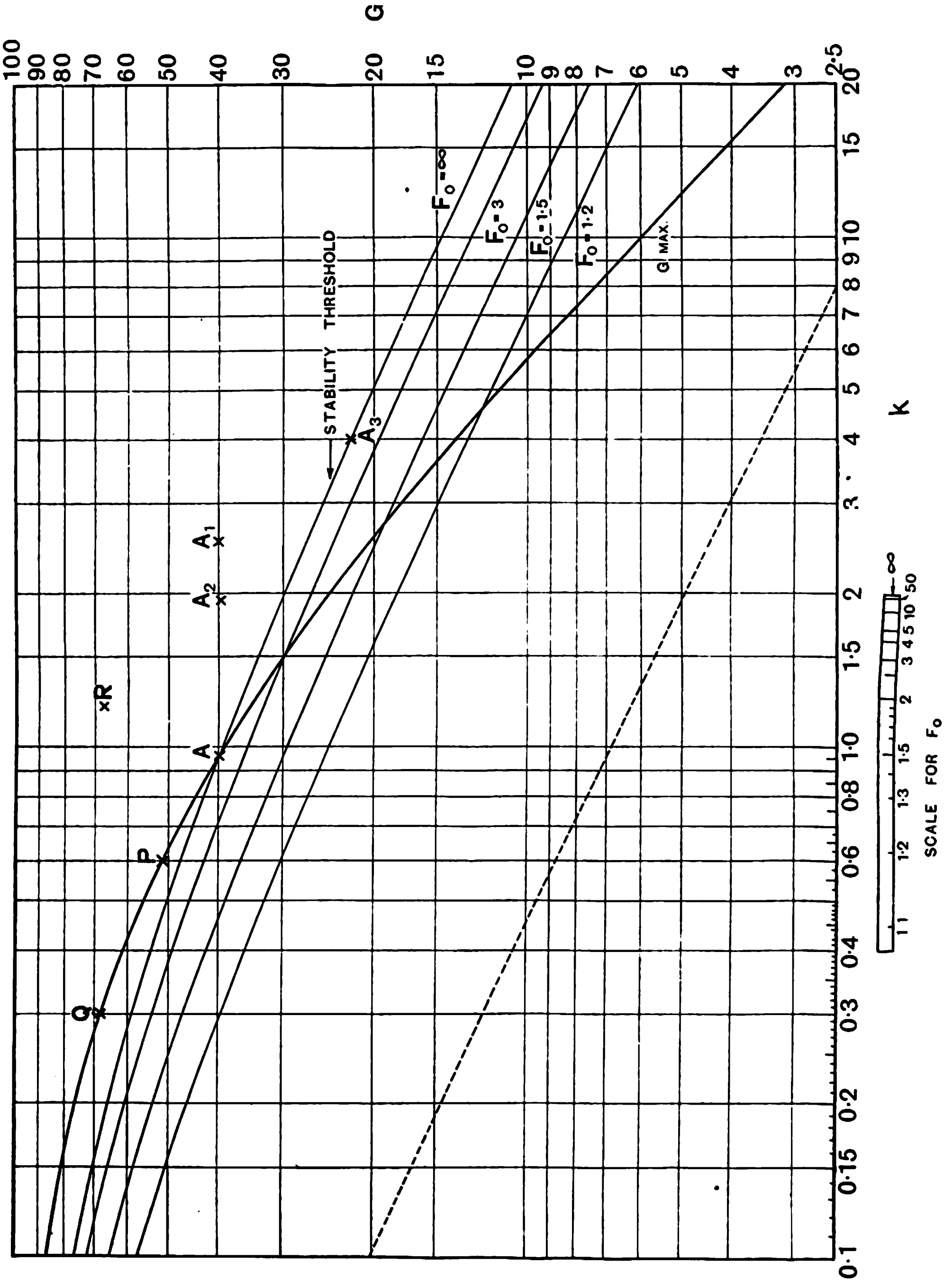


Fig. 13.

H.F. broadcast range from $k=0.5$ to $k=10$ we invariably have a set of coils each of which covers a portion of the range with the help of a variable condenser. The range covered by one coil will be called the *coil range.* The curve giving the maximum G plotted against k will be continuous as the condenser is varied, but on putting in a new coil the curve will jump to a new position so that *we shall have a ladder-like curve with discontinuous rungs.* This curve will be discussed later on, but it will simplify our ideas if in the meantime we assume that in tuning over the *total range* the condenser is fixed and the change from coil to coil is made continuous as with a variometer. In the next section the results will be given under this assumption.

16. Maximum *G* with Fixed Condensers and Variable Coils using the Standard Valve.

$G=g/\sigma_2$ and if we use identical coils and condensers in the grid and plate circuits, $\sigma_1 = r/L^2\omega^2 = C\omega \cdot r/L\omega$ when the coil is tuned to resonance: putting $\omega = k\Omega$ we finally get

$$\sigma_2=\sigma_1+\sigma_v=[k+\sigma_v \cdot L\omega/r \cdot C\Omega]C\Omega \cdot r/L\omega \quad (22)$$

and so

$$G = \frac{g \cdot L\omega/r \cdot C\Omega}{k + \sigma_v \cdot L\omega/r \cdot C\Omega} \quad .. \quad (23)$$

In the case of single layer coils screened by cylindrical copper pots we have found experimentally that $L\omega/r=80$ over a wide range of frequencies. Taking this value, choosing $C=160\mu\mu$F and using the standard data given in the list of symbols, equation (23) becomes the working formula

$$G_{max.} = 64/k+0{\cdot}64 \quad .. \quad (24)$$

This curve is plotted in Fig. 11. It has been deduced theoretically and practically coincides with the experimental curve published in a previous paper.*

When $k=0$ $G_{max.}=100$ showing that at low frequencies the plate load can be made so great that the full valve amplification ($\mu=g/\sigma_v=8\times10^{-4}/8\times10^{-6}=100$) is attained; at frequencies below 970 kilocycles the curve lies in the unstable region above $F_0=\infty$; at higher frequencies stability is assured, but $G_{max.}$ rapidly drops since the plate load is decreasing, and falls to 6 at 10,000 kilocycles ($k=10$).

When the grid and plate circuits are identical, fixed condensers of value 160$\mu\mu$F being used, and tuning over the total range is effected by continuous variation of the coils, the value of $L\omega/r$ remaining fixed at the value 80, equation (24) and Fig. 11 give the maximum stage gain $G_{max.}$ obtainable at any frequency k using the standard valve. The set is unstable at low, stable at high frequencies.

17. Maximum *G* with Fixed Condensers and Variable Coils using any Valve.

In section (13) it was shown how the F_0 curves (Fig. 11) could be displaced to suit any valve, and we shall now see that the $G_{max.}$ curve can be similarly treated. By a slight re-arrangement equation (23) can be written as follows:—

$$g/G \cdot \sigma_v = 1 + k \cdot C\Omega \cdot r/L\omega \cdot \sigma_v \quad (25)$$

Now, as in section (13) we can see how any point Gk on the $G_{max.}$ curve (Fig. 11) will change due to alteration of any constant in the circuit. If g is doubled G must be doubled and k unchanged, so that equation (25) may still hold; if σ_v is doubled G must be halved and k doubled, and so on. Table II shows all the possible displacements of the $G_{max.}$ curve due to circuit alterations, and the arrows in Fig. 14 show these displacements graphically.

TABLE II.

Change from standard circuit where $g=8\times10^{-4}$ amps/volt $\sigma_v=8\times10^{-6}$ mhos $C_0=0.1\mu\mu$F $C=166\mu\mu$F $L\omega/r=80$	Factors by which k and G must be multiplied.	
	k	G
g doubled	1	2
σ_v doubled	2	½
C_0 doubled	1	1
C doubled	½	1
$L\omega/r$ doubled	2	1

Since the $G_{max.}$ curve in Fig. 11 may, when shifted, move out of the field of view it is redrawn over a greater range in Fig. 13.

---

* *E.W. & W.E.*, Oct., 1927, p. 625, Fig. 10, curve 3.

Fig. 13 shows the maximum stage gain $G_{max.}$ for the standard valve and standard circuit with fixed condensers and continuously variable coils. For any other valve or circuit, provided that identical circuits are used for grid and plate, slide the $G_{max.}$ curve parallel to itself according to the rules given in Table II and indicated in Fig. 14.

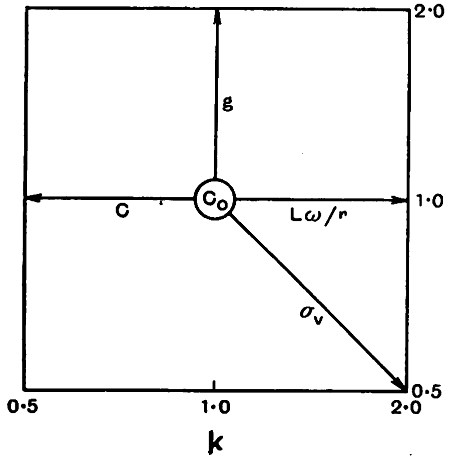


Fig. 14. *Shift of* $G_{max.}$ *curve when any constant is doubled.*

18. Discussion of Fig. 13.

The most striking features shown by the curves are that at low frequencies (k=0.5), although high amplification from grid to plate is possible experimentally, only part of it is available on account of instability, and that at high frequencies (k=10) the stage gain is low, its value being about 6, and the set is well within the stable region.

A study of Figs. 12 and 14 will enable us to foretell the behaviour of the set when changes are made in the design of the valve or circuit. Thus if g is doubled, the $G_{max.}$ curve rises by one unit (all values of $G_{max.}$ doubled), while Fig. 12 shows that all the F_0 curves take one pace upwards and one to the left. If the reader will carry out this operation with the help of tracing paper he will find that the point A (Fig. 13) where the G curve crosses the threshold curve has been shifted to A_1 (k=2.55) and that for frequencies higher than this stability is assured, with the advantage that the stage gain is doubled, while at lower frequencies the increased stage gain is largely useless owing to the stability threshold having risen.

If C_0 is halved, all other constants remaining the same, we find from Fig. 12 that all the F_0 curves take one pace to the right while Fig. 14 shows that the $G_{max.}$ curve is unaltered. Our tracing paper will now show that stability is assured at all frequencies so that we utilise all of the large stage gain at low frequencies but that at high frequencies no improvement results.

These results are not of much moment for single stage amplifiers but are of great importance for multi-stage sets since the stability threshold keeps dropping as the number of stages increases.

Anyhow, the problem of reducing C_0 in a shielded valve below $0.1\mu\mu$F is not easy and is probably keeping valve designers awake at night.

Incidentally, the substitution of a 3-electrode valve with $C_0=5\mu\mu$F will shift the stability boundary to the position shown by the broken curve in Fig. 13. The possible stage gain is now very small: at 8,000 kilocycles it is only 2.5.

19. Further Progress in Valve Design.

The alteration of one valve constant at a time, as considered in section 19, is probably impracticable, but there are two lines of progress which seem possible. Taking as an example a valve in which all electrodes are in parallel planes, we might in the first place put twice the length of filament into the same area, leaving the other electrodes unchanged in size and position, thus doubling the emission per unit area; this would result in doubling g and σ_v leaving C_0 unchanged. Secondly we might double the area of each electrode and also double the filament length, leaving the spacing between the electrodes unchanged. This would result in doubling g, σ_v and C_0. The first method may be called *doubling the filament packing*, and the second, *doubling the valve diameter.*

Figs. 12 and 14 show that the first of these changes would cause all curves in Fig. 13 to move one pace to the right, the stability boundary and maximum stage gain would be raised everywhere, and the frequency below which instability is possible would move from A to A_2. Accordingly, above frequencies of 2 megacycles increased stable amplification would ensue, at lower frequencies the improvement would be partly nullified by instability.

The second type of valve in which the diameter is doubled would leave the F_0 curves unchanged, while the $G_{max.}$ curve would move one pace to the right. The intersection of the $G_{max.}$ curve and the curve $F_0=\infty$ would now be at A_3. At frequencies above 4 megacycles the possible gain would be doubled, at lower frequencies the improvement would be less.

We see that valves of either of the two types discussed would enable higher amplification to be obtained at and below about 70 metres.

The Ladder Curves.

So far it has been assumed that the grid and plate condensers have fixed values and that variometer tuning has been employed: the $G_{max.}$ curve in Fig. 13 is only true for this special assumption. In practice, however, we use a set of coils and tune over each coil range with variable condensers. If, for example, nine sets of coils were used over the total range $k=0.5$ to $k=10$ we should only be on the $G_{max.}$ curve on the nine occasions when the condensers are set at our standard value of 160$\mu\mu$F and each pair of coils is inserted in turn. At all other condenser settings we should be on a completely new set of curves.

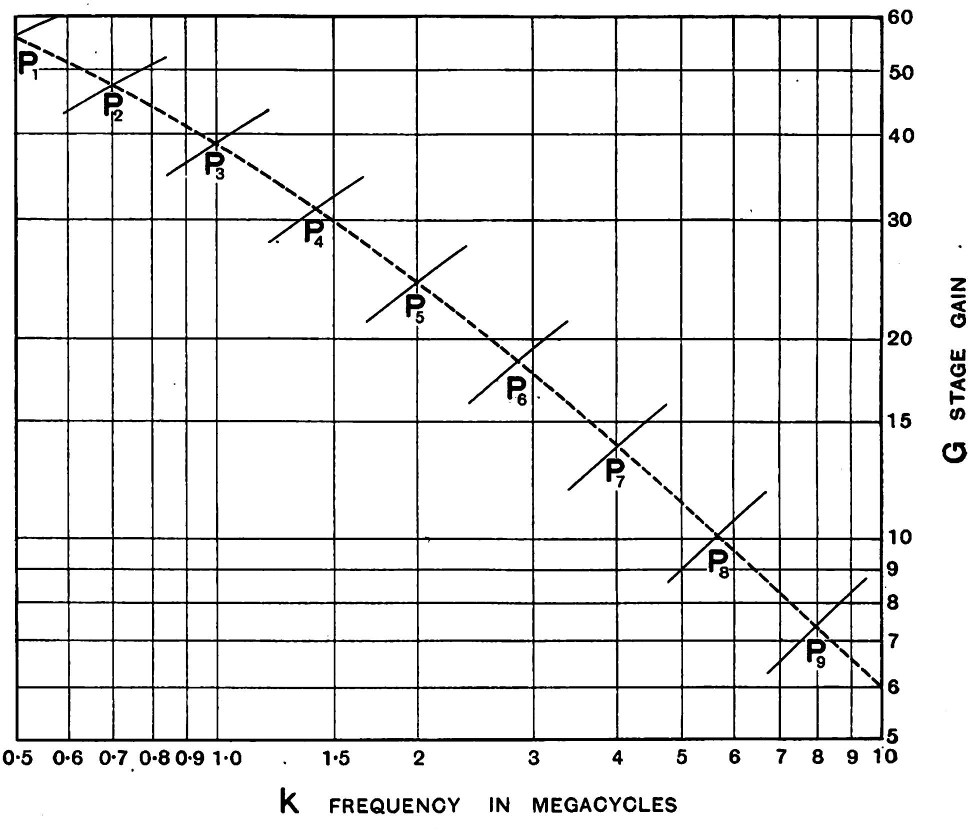


Fig. 15.

We will now investigate the $G_{max.}$ curves obtained by varying the condensers.

Equation (25) gives the relation between $G_{max.}$ and k on the assumption that C is fixed: the variable L does not appear except in the form $r/L\omega$ which is treated as a constant. Our task is to remove C, which has become a variable quantity, and replace it by its equivalent in L which is now fixed as long as the same coil is used.

$C\omega=1/L\omega$ at the tuning point, hence, putting $\omega=k\Omega$, $C\cdot k\cdot\Omega=1/L\cdot k\cdot\Omega$ that is $C\Omega$ can be replaced by $1/k^2\cdot L\Omega$. Accordingly equation (25) becomes

$$g/G\cdot\sigma_v=1+[1/k\cdot L\Omega]\,[r/L\omega\cdot\sigma_v] \quad \dots \quad (26)$$

k appears in the denominator whereas in equation (25) it appeared in the numerator. Thus when k is *halved* in equation (25) a certain change in G is produced; when k is *doubled* in equation (26) the same change in G is produced. Thus in Fig. 13, if we travel from P where $k=0.6$ to Q where $k=0.3$ by variometer tuning, the result of increasing G the same amount by condenser tuning will bring us to R, where $k=1.2$.

Evidently our new path from P to R is the mirror image of our former variometer path PQ as reflected in a vertical line through P.

In Fig. 15 the old $G_{max.}$ curve due to variometer tuning is shown as a broken line. If nine pairs of coils are provided for the total range we shall be on this curve at the nine points P_1 to P_9 as the coils are changed, provided that the condenser settings are fixed at 160μμF. On tuning by the condenser we move along one of the rungs of the ladder, the length of the rung depending on the condenser limits.

In Fig. 15 each rung gives the relation between stage gain and signal frequency when condenser tuning is used. Each rung corresponds to a particular pair of equal coils. Upward movement along a rung corresponds to decreasing condenser settings. The broken curve corresponds to variometer tuning with $C=160$μμF. For any other standard C the whole ladder must be displaced horizontally according to the rule given in Table 2.

The ladder curves are capable of giving an enormous amount of information as to the design and behaviour of a set, but the limitations of space allotted to this paper do not allow further discussion of them at present.

LIST OF SYMBOLS.

C σ	Capacity of	any tuned circuit.
C_g σ_g	- —— -	grid circuit.
C_p σ_p	Conductance in	plate circuit.
C_1 σ_1	parallel with	equivalent grid circuit.
C_2 σ_2		equivalent plate circuit.
σ_v	Differential conductance of valve.	
C_0	Grid-plate capacity of valve.	
L	Inductance of any circuit.	
L_1	Inductance of grid circuit.	
L_2	Inductance of plate circuit.	
r	Resistance in series.	
R	Resistance in parallel.	
e	A.C. E.M.F. injected in series with grid coil.	
e_1	A.C. voltage of grid.	
e_2	A.C. voltage of plate.	
i	Any A.C. current.	
ω	$2\pi\times$ signal frequency in cycles.	
Ω	$2\pi\times10^6$ cycles.	
k	Signal frequency in megacycles (=cycles $\times10^6$)	
μ	Voltage amplification of valve.	
g	Mutual conductance of valve: amps/volt.	
θt	Phase angle in	any tuned circuit.
$\theta_1 t_1$	- —— -	equivalent grid circuit.
$\theta_2 t_2$	Tangent of phase angle in	equivalent plate circuit.
H	$g\cdot C_0\omega/\sigma_1\sigma_2$.	
$1/F$	$(1+jt_1)(1+jt_2)+j\cdot H$.	
F_0	Max. value of F obtained by tuning: voltage gain from signal to plate on tune due to reaction.	
A	Voltage gain from signal to plate on tune without reaction.	
G	Voltage gain from grid to plate without reaction: stage gain.	
$G_{max.}$	Largest G obtainable experimentally.	

Constants of Standard Valve.

g	8×10^{-4} amps/volt.
σ_v	8×10^{-6} mhos.
C_0	0.1μμF.

Constants of Standard Grid and Plate Circuits.

$L\omega/r$	80.
C	160μμF.

The Power Factor and Capacity of the Electrodes and Base of Triode Valves.

With special reference to their use in Thermionic Voltmeters.

A PAPER with this title was read by Mr. G. W. Sutton, B.Sc., at a recent meeting of the Physical Society. The requirements for a valve voltmeter for H.F. resistance measurements are (1) that it puts the smallest possible load on the circuit to which it is connected, (2) that its readings should be proportional to the square of the voltage, and (3) that it should be rapid in indication.

Unlike a thermo-junction a voltmeter must be connected across points differing in P.D., thus increasing the capacity by 5 to 10$\mu\mu$F, but unlike an electrostatic voltmeter the capacity does not vary with the reading. More serious are the losses in the voltmeter, which, using the anode bend, may double or treble the decrement of the circuit under investigation. The valve holder and base may introduce considerable additional losses. Measurements by Hartshorn and Jones suggested that the glass pinch was a worse offender than the compound base but this is not borne out by Mr. Sutton's measurements, the results of which are given in the following table.

These results indicate the importance ot removing the cap before using a valve in a valve-voltmeter. By adopting this device and carefully arranging the leads and by applying —4.2 volts grid bias, the increase of the circuit decrement due to the voltmeter was reduced from 18 to 1.8 per cent. in a given example.

With regard to the attainment of the square law, Mr. Sutton shows that for a given valve it is possible to find values of anode voltage and grid bias such that the departure from the average value of the constant $V/\sqrt{\theta}$ does not exceed 0.4 per cent. A method is described whereby the best values can be determined experimentally.

To obtain rapidity of reading Mr. Sutton recommends the use of a pivoted and critically damped moving-coil galvanometer of short period.

	(f=650kC)	$C(\mu\mu F)$.	P.F.
(a)	Modern " low-loss " valve-holder (sockets mounted on narrow insulating ring of large diameter)	1.4_8	0.04
(b)	French D.E. valve	7.0_0	0.02_1
(c)	Ditto base alone	1.1_0	0.1_0
(d)	Valve base found previously to have very low insulation resistance	2.4_2	0.37
(e)	English D.E. valve	4.9_6	0.03_4
	Ditto base alone	1.5_8	0.05_5
	Ditto remainder alone—*i.e.*, pinch, electrodes and leads	3.0_6	0.02_0
	(f=545kC)		
(f)	" R " valve. Metal ring on cap...	5.0_5	0.06_3
	Ditto base alone	1.8_3	0.17
	Ditto remainder alone	2.9_0	0.00_3
(g)	" R " valve. Another manufacturer	4.6_2	0.04_9
	Ditto base alone	1.7_2	0.09_6
	Ditto remainder alone	2.5_8	0.02_8*
(h)	D.E.R. valve. Bakelite cap	4.4_1	0.01_5
	Ditto base alone	0.7_5	0.05_4
	Ditto remainder alone	3.2_2	0.00_{15}
(i)	D.E.R. Old pattern, before the use of " gettering " ...	5.1_1	0.03_5
	Ditto base alone	1.6_1	0.05_4
	Ditto remainder alone	3.2_3	0.02_7

* It was noticed that the under surface of the glass pinch was oily. This may have accounted for the comparatively high value of the P.F. in this case as compared with the others.

The Accuracy and Calibration Permanence of Variable Air Condensers for Precision Wavemeters.

By W. H. F. Griffiths, A.M.I.E.E., Mem.I.R.E.

Introduction.

THE accuracy of a substandard wavemeter is always limited by the constancy and degree of law conformity of its variable air condenser, so much so, in fact, that it is almost impossible, for this reason, to construct a substandard instrument having an overall inaccuracy of less than 5 parts in 10,000 for an appreciable range of frequency and continuously variable.

For reasons of "stray" capacity variabilities and circuit capacity inconstancy the minimum capacity of such a wavemeter is usually not less than 500 or 1,000$\mu\mu$F for moderate frequencies although it may be somewhat lower for ultra high frequency bands. Even so, since capacity variations with age of the order 1 or 2$\mu\mu$F are generally expected even in variable condensers of the highest quality, uncertainties to the extent of 1 or 2 parts in 1,000 in capacity are always possible and introduce frequency uncertainties of the order of 1 part in 1,000 if a considerable period of time has elapsed since the calibration of the substandard against a *standard* of frequency.

These capacity uncertainties are discussed in the first part of the article and in the second part is described an entirely new design of variable air condenser by the use of which it is hoped to fill, more effectively, the gap which exists between good commercial heterodyne wavemeters having an overall accuracy of, say, 2 parts in 1,000 and the modern multivibrator standard of radio frequencies. The standard multivibrator wavemeter,* due to Dr. Dye of the National Physical Laboratory, may be relied upon to within 1 or 2 parts in 100,000, the elinvar tuning fork, with which the frequency of the Abraham Bloch harmonic producing multivibrator is controlled, being standardised for frequency with great accuracy against a standard clock using a specially constructed phonic wheel as a means of effecting the comparison. Moreover, the temperature coefficient of the fork is of a very low order—of the order of 1 part in 100,000 per degree Centigrade.

Full use cannot be made of the high degree of accuracy now obtainable in frequency determinations by a standard such as this if really good substandards of greater accuracy than 1 part in 1,000, of great conformity to law and having continuously variable and extensive ranges of adjustment, are not available. In such a variable substandard the new design of variable air condenser would be employed.

PART I.

The necessity for a high degree of calibration accuracy and permanence of variable air condensers of good quality substandard wavemeters is generally appreciated. It is, however, not always realised how difficult it is to obtain these essential qualities even in condensers of the highest precision.

The oscillatory circuit of a wavemeter usually comprises a reactance the value of which is fixed at any given frequency and one of opposite sign which is adjustable, and for still greater convenience the adjustable reactance is usually made continuously variable. If the L/C ratio of the circuit is correctly chosen it matters not which of the two reactances is made variable, but in multi-range wavemeters it is convenient to make the capacity reactance continuously variable by using a variable air condenser, so that a number of inductances may be selected for association with it. It would be unwise to employ a single variable inductance in conjunction with a number of fixed capacities for range extension for several reasons.

---

* D. W. Dye, *Phil. Trans. Roy. Soc.*, Ser. A, 224 (1924), 259; also W. H. F. Griffiths, *The Wireless World and Radio Review*, Vol. XVI., No. 296.

Reasons for using Variable Condensers.

The capacity of a wavemeter circuit cannot have any value to suit a variable inductance of a definite limited range, because of the difficulty of obtaining high value capacities (of convenient bulk) having negligibly low temperature coefficients and constancy of value generally and also because of the fact that "stray" capacities which augment the circuit capacity are of a more or less constant order and not proportional to the value of the latter and therefore impair seriously the accuracy when it is of a low order. Slight changes of position of conducting masses of the wavemeter or of neighbouring conductors, changes of wiring and changes of so-called "earth capacities" introduced by the body during operation, all produce serious inaccuracies when the circuit capacity is small. The capacity of a precision wavemeter is, for these reasons, limited therefore to a range of about $300\mu\mu F$ to $3{,}000\mu\mu F$.

It is convenient to make the capacity variable and to use this in conjunction with a number of interchangeable inductances for yet another reason.

In order to keep the "sharpness of tuning" of the same order throughout a wide range of wavelength, the decrement of the wavemeter circuit must be maintained roughly constant, and this cannot be so if the capacity is varied throughout wide limits. The ideal resonant circuits are those, perhaps, in which the ratio of L/C is maintained approximately constant, but since this is impracticable, it is better that this ratio shall increase with wavelength rather than decrease, as the following tables will show.

TABLE I.

Variable *inductance* mean values $L = 100\mu H$ $R = 1.0\Omega$.

C μF	$\frac{L}{C}$	λ metres	f	ω	ωL Ω	R Ω	$\delta = \frac{R}{2fL}$
0.0001	10^6	188	1.6×10^6	10×10^6	1,000	1.0	0.003
0.001	10^5	592	0.5×10^6	3.2×10^6	320	1.0	0.010
0.01	10^4	1,885	0.16×10^6	1.0×10^6	100	1.0	0.032

TABLE II.

Variable *capacity* mean value $C = 0.001\mu F$.

L μH	$\frac{L}{C}$	λ metres	f	ω	ωL Ω	R Ω	$\delta = \frac{R}{2fL}$
10	10^4	188	1.6×10^6	10×10^6	100	0.32	0.01
100	10^5	592	0.5×10^6	3.2×10^6	320	1.0	0.01
1,000	10^6	1,885	0.16×10^6	1.0×10^6	1,000	3.2	0.01

Table I illustrates, as an example, a resonant circuit having a total wavelength range of 10 to 1 obtained by a variable *inductance*, of mean value $100\mu H$ and mean resistance 1.0Ω, and a number of fixed capacities ranging from $0.0001\mu F$ to $0.01\mu F$. The three capacity values given in the tabulation are, of course, not intended to be the actual number of ranges required to cover the total wavelength range—many more would be required in practice. The capacities are assumed to be of air dielectric and to have, in consequence, negligibly low equivalent series resistance values. It is assumed also that the effective resistance of the inductance remains approximately constant throughout the whole range of frequency; although there will, in practice, be an increase of resistance with frequency, it need not be great over a limited range in a well-designed coil when the applied E.M.F. is induced into the whole coil.

It will be seen that while the resistance of the circuit remains constant the reactances *decrease* proportionally with frequency, resulting in a rapidly increasing decrement.

If, however, the *capacity* is made variable about a mean value of, say, $0.001\mu F$ and a number of fixed value inductances ranging from $10\mu H$ to $1,000\mu H$ are employed (as indicated in Table II), the resistance of the coils will increase, as a crude approximation, proportionally to the root of the inductance, and, since the reactances of the circuit will *increase* proportionally with frequency in this case, the decrement remains of a constant order.

The resonant circuit in which the condition of constant ratio of resistance to reactance can be maintained throughout its range, is the ideal from the tuning sharpness point of view and these tables merely serve to illustrate the fact that this condition is best obtained by keeping the capacity of a more or less constant *order* and by associating it with a series of fixed inductances of widely differing values, because the resistance of any resonant circuit resides almost entirely in its inductance.

For all these reasons, therefore, it is more convenient to follow the usual practice of employing a variable condenser and fixed inductances, but, unfortunately, a more permanent arrangement would be that of a variable inductance and a number of fixed air condensers. Fixed inductances and fixed *air* condensers have roughly the same order of permanence of value, but it is much more difficult to obtain a high order of calibration permanence in a variable condenser than in a variable inductance due to the fact that small changes in the geometry of the former are of much greater importance than are changes of similar magnitude in the case of the latter.

The Difficulties of Variable Condenser Construction.

A variable condenser which will "hold" its accuracy of calibration over a period of time can only therefore be obtained by the most careful design and construction. This particularly applies to the initial setting of the two sets of plate conductors to ensure uniformity of dielectric air gaps.

It is not only necessary for the plates of each system to be set perfectly parallel and for the moving plates to rotate truly in relation to the fixed plates, but it is necessary also for each moving plate to rotate exactly midway between the pair of fixed plates with which it interleaves.*

The reason for this is that since the capacity between the adjacent moving and fixed plates is connected with the distance between them by an inverse law, it follows that the percentage change of capacity (for a given scale setting) due to a given change of position of one bank of plates, axially, relative to the other, will be a minimum when the distance between *all* adjacent plates is a maximum. This can only occur when the distances between all adjacent plates are equal, and in this condition the capacity of the condenser is, of course, a minimum for any given scale reading.

The Effect of Gap Equalisation on the Permanence of a Variable Air Condenser.

Let d_1 and d_2 be the distances of the dielectric gaps (of uniform dielectric constant) between a moving plate and adjacent upper and lower fixed plates respectively, then the capacity of this element of the plate assemblage is proportional to

$$\frac{1}{d_1}+\frac{1}{d_2}$$

$$\therefore\ C \propto \frac{d_1+d_2}{d_1\,d_2} \quad \text{but } d_1+d_2 \text{ is constant}$$

$$\therefore\ C \propto \frac{1}{d_1 d_2}$$

Since the capacity is inversely proportional to two quantities the sum of which is constant, it is generally thought that for very small differences of gaps the resultant capacity change is negligible. This is far from being the case however even in modern condensers of precision, the effect upon both the permanence of calibration and upon the general conformity to law being very marked, the latter may generally be taken as a criterion of the former.

---

* Since the present article was written this necessity has been more concisely dealt with by Messrs. Braillard and Divoire in the June issue of *E.W. & W.E.*

The curves of Fig. 1 show, for various displacements of plates from their exact mid-positions, the decrease of the product of adjacent air gap distances and the consequent increase of the reciprocal of this quantity, $1/d_1d_2$, to which the resultant capacity is proportional.

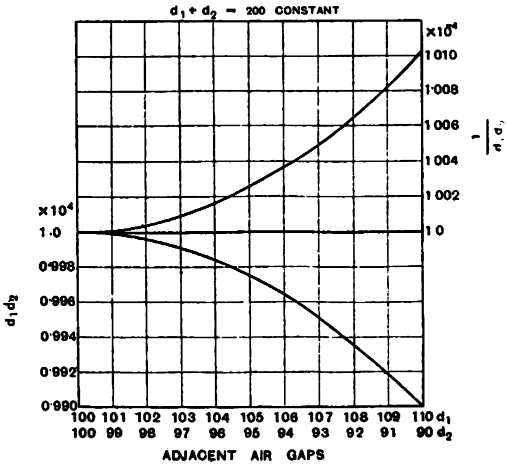


Fig. 1.

Fig. 2 shows how the effect of any post-calibration mechanical changes in plate positions is magnified if the adjacent gaps are not initially *exactly* equalised. From this set of curves can be found the percentage change of capacity due to any *post-calibration* percentage axial displacement of one set of plates relative to the other for various percentages of *initial* axial displacement of that set of plates from the exact mid-positions between the others. The curves marked with positive percentages correspond with cases where the *error producing displacement* is in the same direction as the *initial displacement* and those marked with negative percentages where the initial and subsequent displacements are in opposite directions. The curve marked zero indicates the capacity change which occurs for various post-calibration changes when all dielectric gaps have been initially set equal.

These curves are not, however, as convincing as they should be owing to the fact that they are plotted to a scale which emphasises those portions of the curves for which the changes subsequent to calibration are of the same order as the initial plate displacement. The capacity changes produced are therefore, in this region, not much increased by the want of initial gap equalisation. The lower portions of these curves plotted for very small capacity changes are given in Fig. 3 and show well the importance of initial gap equalisation. It should be noted that these curves (Fig. 3) represent more nearly, quantitatively, the displacement and capacity change likely to be experienced in good quality condensers.

It will be observed that a 1 per cent. post-calibration displacement will have little effect on the capacity of a condenser if the gaps have been carefully equalised, but effects a 0.2 per cent. capacity change if there is an initial axial displacement of one set of plates relative to the other amounting to 10 per cent. of the mean gap, an error about twenty times greater than would have been the case had the gap equalisation been perfect.

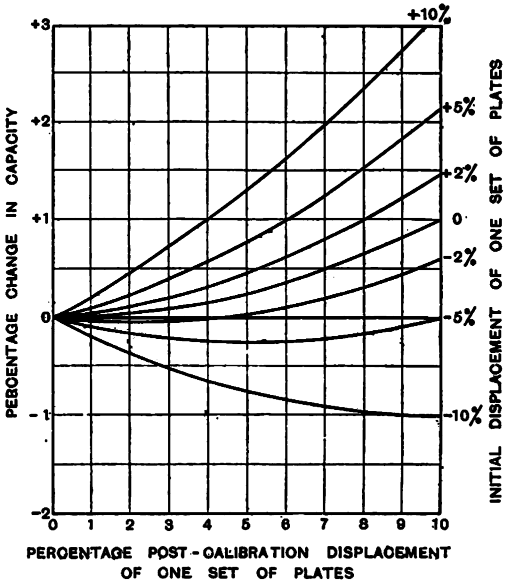


Fig. 2.

It is interesting to note that, as a safeguard against inaccuracies introduced by the sagging of the moving plates, if these plates could be set 2 per cent. *high* in the gaps between the fixed plates, a sagging up to 4 per cent. of the mean gap would produce very little effect on the capacity. The initial setting of the moving plates 2 per cent. from the mid-position is, however, a very difficult operation.

The curves of Fig. 4 show the percentage capacity change produced by 1 per cent., 2 per cent. or 3 per cent. post-calibration gap changes for various values of initial plate displacement.

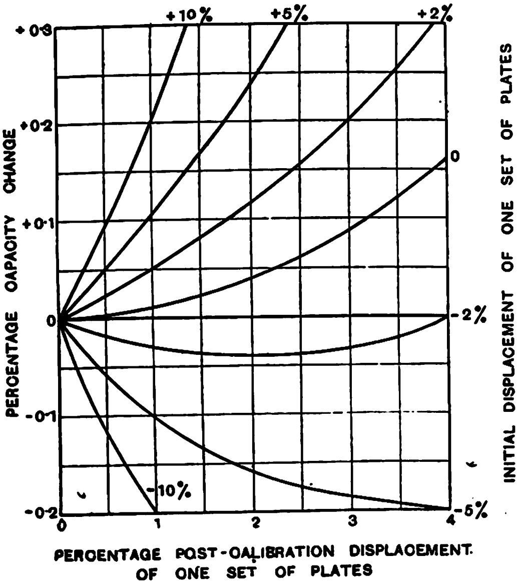


Fig. 3.

Gap Equalisation an Aid to Law Conformity.

This important feature of construction affects not only the degree of calibration permanence but also the degree of conformity to the mean law connecting capacity with angular movement.

Small general and local irregularities which would produce only negligible departures from the mean law if the plates were absolutely equidistant will produce law departures by no means inconsiderable if this initial plate setting has not been effected or insufficient care exercised in this operation.

As an example of this effect the case of a condenser whose moving plates have a "wobble" of about 10 per cent. of the mean gap due to their revolving at an angle of about 8′ out of truth with the fixed plates, will be taken. The angle of 8′ corresponds to a 10 per cent. "wobble" with a plate radius of 4 inches and a dielectric gap of 0.1 inch. Let it be assumed that this wobble is such that the moving plates commence to enter the bank of fixed plates correctly in their mid-positions so that the rate of change of capacity, $dC/d\theta$, at the commencement of the scale is a minimum. As the angle θ of plate envelopment is increased, however, the moving plates become more and more displaced from their mid position at entrance to the fixed plates until, at $\theta=90°$, the displacement is 10 per cent. and is gradually reduced again to zero at $\theta=180°$. Such a wobble is, of course, small but may be very serious in its effect on the law.

In Fig. 5 is plotted (curve A) a curve giving the percentage departure from the correct calculated "slope," $dC/d\theta$, for a condenser having this imperfection, the slope increasing until the moving plates are half entered and then commencing to decrease until the *entering* portions of the moving plates once more regain their mid-positions at the 180 degrees setting. Curve B shows the corresponding deviation from the law for the same degree of wobble when the moving plates are initially displaced, axially,

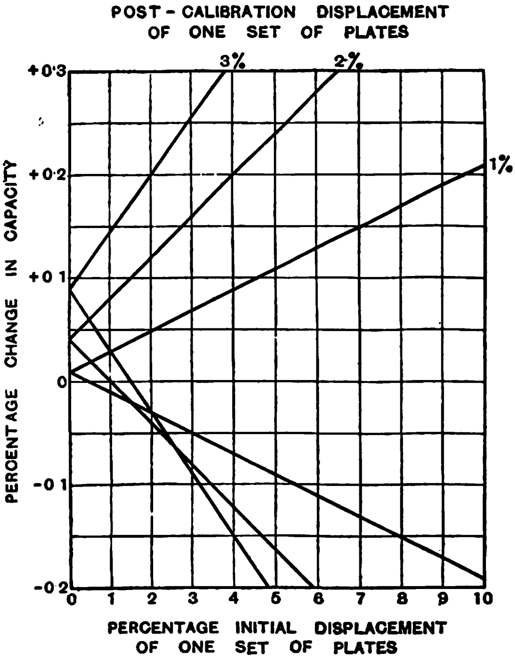


Fig. 4.

in the direction of the wobble, by 10 per cent., and shows well the effect of such an initial displacement upon the law of the condenser.

An Example of Modern Precision Condenser Accuracy.

A modern precision condenser having a law departure not greater than that corresponding to curve *A* would be considered good and it is interesting to compare this calculated curve with one plotted from measurements on an actual condenser.

The curve *A,* since it is plotted from a computation of errors from the *ideal* law, appears as a wholly positive error, but in practice the average error would be reduced by calculating the deviations on either side of a *mean slope,* the corresponding percentage slope deviation being indicated by curve *C* of Fig. 5.

Curve *D* of this figure is plotted from actual National Physical Laboratory measurements on a large precision air condenser by Messrs. H. W. Sullivan, Ltd., and shows remarkable similarity to the calculated curve *C* (although it is not suggested that the cause for the peculiar curve shape has thus been diagnosed). The average deviation from the law is seen to be very small over the useful range of the condenser. It is thought that a full statement of actual measured capacities and variously expressed errors for this condenser will be of use in helping to form a clear idea of what one may expect from a good quality modern laboratory condenser and these are therefore tabulated below. The mean law of the condenser computed from all capacity values between 27 degrees and 144 degrees (inclusive) was found to be $C=3.0173\ \theta+59.80$, and the third column of Table 3 gives the values computed from this linear law.

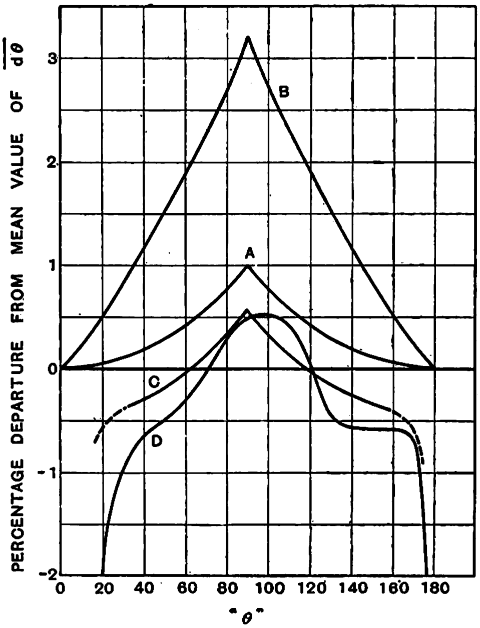


Fig. 5.

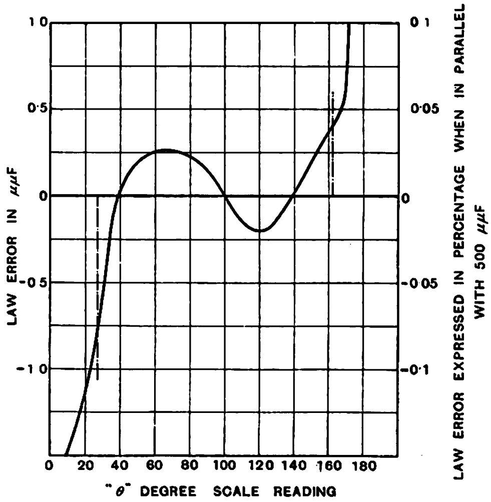


Fig. 6.

The fourth column gives the error introduced by assuming the law to be correct at any point and in column 5 these errors are expressed as percentages of the correct capacity for the various settings.

In all precision wavemeters the "zero" of the variable condenser is "set-up" by paralleling with it a fixed condenser of great constancy of value and in column 6 therefore the percentage law inaccuracy is given when a fixed capacity of 500μμF is paralleled with the variable condenser under examination. Wavelength inaccuracies corresponding with these capacity departures are given in column 7.

In column 8 the actual slope, $dC/d\theta$, is given and in the final column the percentage departure from the mean value of $dC/d\theta$, the curve of which has already been plotted in Fig. 5 (*D*).

It will be seen that the departure from the law at any point throughout the range of the tabulation is almost within the accuracy of measurement of capacities of this order. In this connection it should be noted that the measured capacity values given in the second column originally had their fourth significant figures dropped showing that the accuracy of measurement was of the order of $\pm 0.1 \mu\mu$F.

TABLE III.

θ Degrees	C $\mu\mu$F	C Law value	Law Error $\mu\mu$F	Law Error %	Error of $C+500$ %	λ Error %	$\frac{dC}{d\theta}$	Slope Error %
27	141.6	141.27	—0.30	—0.20	—0.04	—0.020	2.990	—0.89
36	168.5	168.42	—0.08	—0.05	—0.01	—0.005	3.000	—0.56
54	222.5	222.74	+0.23	+0.10	+0.03	+0.015	3.010	—0.24
72	276.7	277.05	+0.25	+0.09	+0.03	+0.015	3.027	+0.33
90	331.2	331.36	+0.16	+0.05	+0.02	+0.010	3.033	+0.53
108	385.8	385.67	—0.13	—0.03	—0.015	—0.007	3.022	+0.16
126	440.2	439.98	—0.18	—0.04	—0.019	—0.009	3.000	—0.56
144	494.2	494.29	+0.10	+0.02	+0.01	+0.005	3.000	—0.56
153	521.2	521.45	+0.25	+0.05	+0.02	+0.010	3.000	—0.56
162	548.2	548.61	+0.41	+0.07	+0.04	+0.020		
	Measured values		See curve of Fig. 6		See curve of Fig. 6			See Curve D Fig. 5

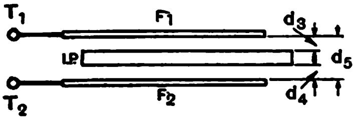


Fig. 7.

The curve of Fig. 6 shows the error of capacity value introduced at any scale setting by assuming the law to be obeyed perfectly and the same curve approximately represents the *percentage* capacity error with the fixed capacity in parallel if the right-hand scale is used.

PART II.

The necessity for "Series" Dielectric Gaps and the advantages of making adjacent Gaps complementary.

In order to eliminate largely errors of calibration due to want of permanence and non-conformity to law inherent in ordinary variable condensers of the rotary plate type, the author has recently devised a new variable air condenser* of the interleaved plate type. In this condenser not only are the adjacent dielectric gaps electrically in series instead of parallel but are also complementary.

If, in Fig. 7, F_1 and F_2 are adjacent fixed plates electrically insulated one from the other and connected to the terminals T_1 T_2 of the system and *IP* is an intermediate conducting plate (moving plate) inserted in the field between these plates and insulated from them, then the two gaps d_3 d_4 are electrically in series, so that, their reactances being added arithmetically, the resultant capacity of the combination will be, for any given scale setting, inversely proportional to the sum of the two gaps.

---

* Patent application made by H. W. Sullivan, Ltd., and the author.

If C_3 is capacity of dielectric gap d_3,
C_4 ,, ,, ,, ,, ,, d_4
and C ,, the resultant of the two gaps in series.

$$\frac{1}{C} \propto \left(\frac{1}{C_3}+\frac{1}{C_4}\right) \propto \left(\frac{1}{1/d_3}+\frac{1}{1/d_4}\right)$$

$$\propto d_3 + d_4$$

$$\therefore \quad C \propto \frac{1}{d_3 + d_4}$$

which remains constant irrespective of changes of position of the intermediate conductor plate *IP* which is inserted between, but not connected electrically, to either terminal system.

The capacity variation of such a system with the intermediate plates *IP* inserted and withdrawn from the fixed plates will, of course, be proportional to the effective reduction of dielectric gap, *i.e.*,

$$\frac{C_{max.}}{C_{min.}} = \frac{d_5}{d_3 + d_4}$$

It is only necessary, therefore, to make the moving plates thick compared with the gaps $d_3\,d_4$ in order to obtain an appreciable capacity variation.

It is relatively easy to ensure that two sets of interleaved plates to which are connected the two condenser terminals $T_1\,T_2$ are fixed rigidly relatively even though they are insulated from each other, and so constancy is ensured by making the only moving part the system of intermediate conductors, as Fig. 8, in which all the intermediate plates *IP* must, of course, be insulated from one another by the insulating material collars $W_1\,W_2$.

This arrangement, therefore, ensures that a want of truth of rotation of a moving plate does not cause a deviation from the general design law connecting capacity with angular position of moving plates and also that "end-play" of the spindle (carrying the moving plates) in its bearings will not produce, for any given angular position of moving plates relative to fixed plates, any change of capacity. Thus, even when such lateral movement of the moving plate system occurs at the time of, or subsequent to, calibration it is of no consequence.

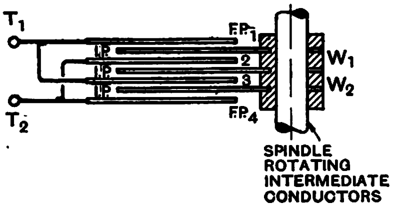


Fig. 8.

Moreover, whether the movable plate accurately travels in its own plane or not, any local permanent or varying deviations of its surfaces from that plane due to kinks or bends, will not, if the plate thickness is uniform, cause any local deviations from the general law of capacity increase with angular displacement of movable plate.

It is obvious that the two adjacent gaps on either side of a moving plate must be complementary in order that all the above advantages may be obtained in one instrument, *i.e.*, that one gap must be the complement of the other in order that at *all* points in the area over which the moving and fixed plates interleave, the sum of the two adjacent air gaps shall be constant.

(*To be continued.*)

The Attenuation of Wireless Waves Over Land.

Paper read by Mr. R. H. BARFIELD, M.Sc., A.M.I.E.E., before the Wireless Section, Institution of Electrical Engineers, on Wednesday, 7th December, 1927.

ABSTRACT.

THE paper gives an account of work by the author on the attenuation of wireless waves over land, in continuation of work on the attenuation due to the earth's surface previously described by the author in conjunction with Dr. R. L. Smith-Rose.*

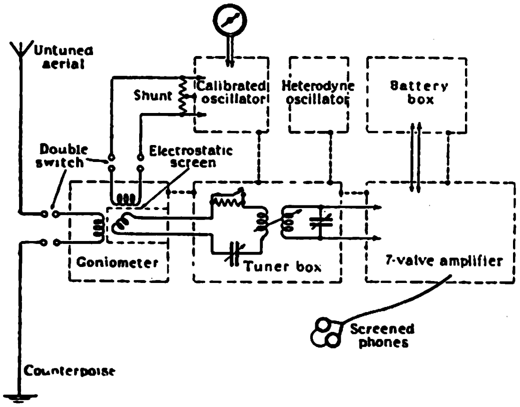


Fig. 1.

Theexperimental work described in the present paper was mainly confined to making intensity measurements with portable apparatus on the normal transmissions from the London Broadcasting Station (2LO, 364 m.) along seven different directions and at distances of from 5 to 100 miles. Within these ranges in daytime there is no appreciable reflection from the upper atmosphere, so that the intensity of the ground ray only was obtained.

The directions along which the measurements were made are set out in Table I, and are also shown in the contour map of Fig. 7.

TABLE I.

Approx. direction.	Length of run.	Town nearest end of run.	Date.
	km.		
N.	115	Huntingdon	Oct., 1926
N.E.	140	Norwich	Sept., ,,
E.	110	Deal	Aug., ,,
S.S.E.	90	Pevensey	Oct., ,,
S.S.W.	90	Chichester	Sept., ,,
W.	160	Bath	May, ,,
N.W.	160	Birmingham	June, ,,

The points at which measurements were made were selected so as to be as far away as possible from such objects as trees and telegraph wires likely to produce local variations in field strength. A fixed intensity measuring apparatus at the Radio Research Station, Slough, took check measurements as nearly as possible simultaneously with those of the portable set. These showed that the radiation from the transmitter remained sensibly constant, the variation over the whole period not being great enough to necessitate any correction.

The general scheme of the apparatus is shown in Figs. 1 and 2.* A radiogoniometer is used as a convenient coupling, a change-over switch enabling either the aerial circuit or the local reference circuit to be joined to the appropriate field-coil. The aerial circuit being first tuned to the signal, the switch is then thrown to apply the local source

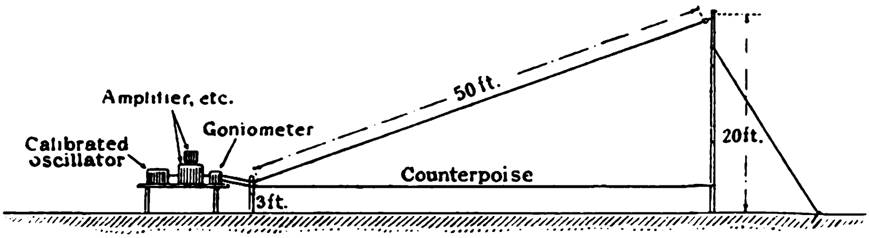


Fig. 2.

---

*J.I.E.E., 1926, Vol. 64, p. 786.

* The author's original figure numbers are adhered to throughout this Abstract.

which is tuned to exactly the same wavelength. The goniometer search coil is then rotated and the switch continuously reversed until a position is obtained for which the signal intensities are equal for both sides of the switch. The tangent of the angle made by the search coil axis with that of one of the local-source field coils then gives the ratio of the current in the aerial to that in the local-source output circuit. The method provides an accurate and easily controlled means of varying the relative effects of the two sources until they are equal. The fact that it obeys a tangent law makes it capable of embracing a large range of intensities.

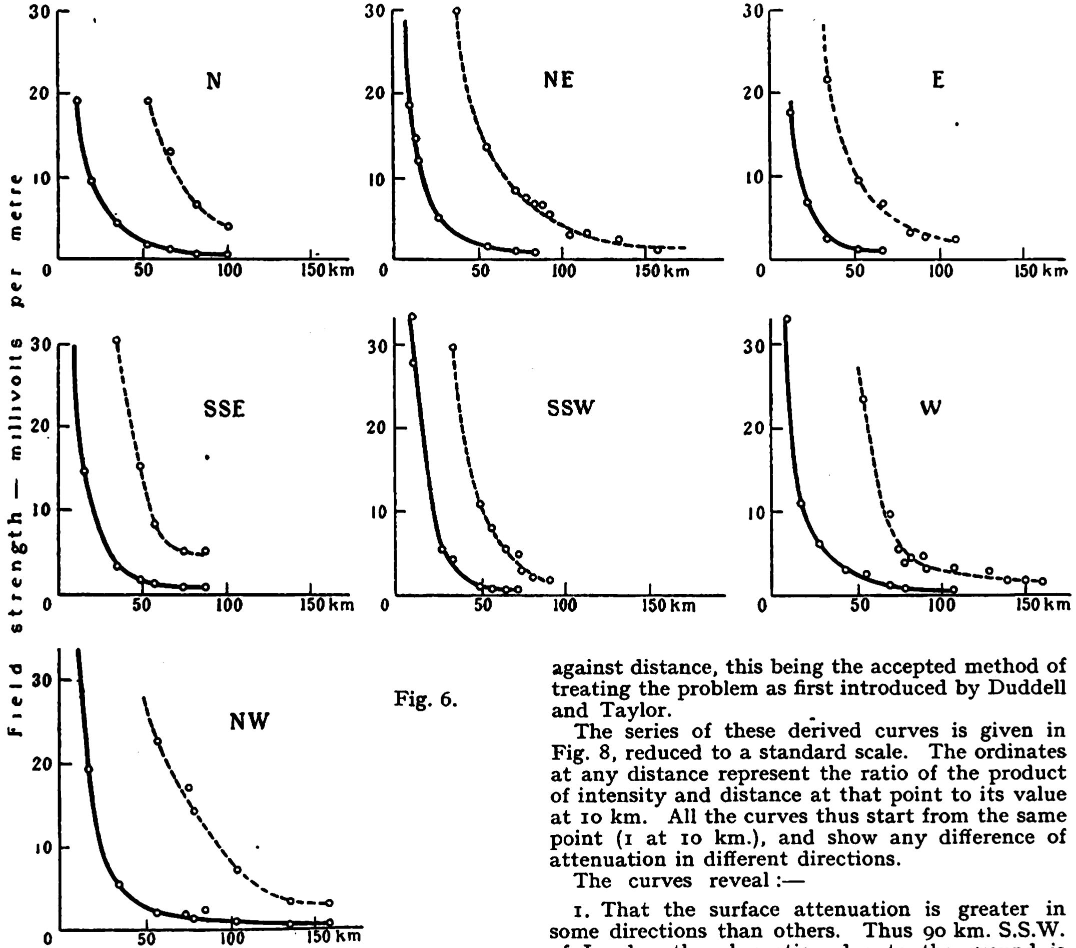


Fig. 6.

The apparatus was calibrated by means of a local small-power transmitter over a range of intensities approximately equal to that covered by the experiments. The relative values of signal strength as measured on the portable apparatus were converted to absolute values in millivolts-per-metre by comparison with measurements of the absolute value at one site (Slough).

The curves of Fig. 6 show the whole of the data obtained and utilised to construct the contour map of Fig. 7.

In order to ascertain the attenuating effect of the earth's surface, it is necessary to separate this effect from the normal attenuation due to the spreading out of the waves. This separation can be effected by deriving a series of curves in which the product of field strength and distance is plotted against distance, this being the accepted method of treating the problem as first introduced by Duddell and Taylor.

The series of these derived curves is given in Fig. 8, reduced to a standard scale. The ordinates at any distance represent the ratio of the product of intensity and distance at that point to its value at 10 km. All the curves thus start from the same point (1 at 10 km.), and show any difference of attenuation in different directions.

The curves reveal :—

1. That the surface attenuation is greater in some directions than others. Thus 90 km. S.S.W. of London the absorption due to the ground is nearly five times as much as in the N.W. direction. The directions may be classified in order of increasing attenuation :—

   (*a*) Directions from London, N., N.W., N.E.
   (*b*) Directions from London, E., W.
   (*c*) Directions from London, S.S.E., S.S.W.

2. Curves in the same group agree very well.

3. The N. curve has an unexpected shape.

4. No trace of any effect due to hills can be seen in the curves, although many of the directions passed over low hills, *e.g.*, South Downs, Chilterns and Cotswolds.

The author then proceeds to consider the theoretical value of attenuation deduced in accordance with Sommerfeld's work on the theory of attenuation. Theoretical values are shown in Fig. 9 for various values of σ, the conductivity of the earth's surface, and by comparison with these curves a value for apparent conductivity can be found for each of the experimental curves of Fig. 8. In Fig. 10 experimental and theoretical curves are superimposed, the two cases selected being the best and worst "fits."

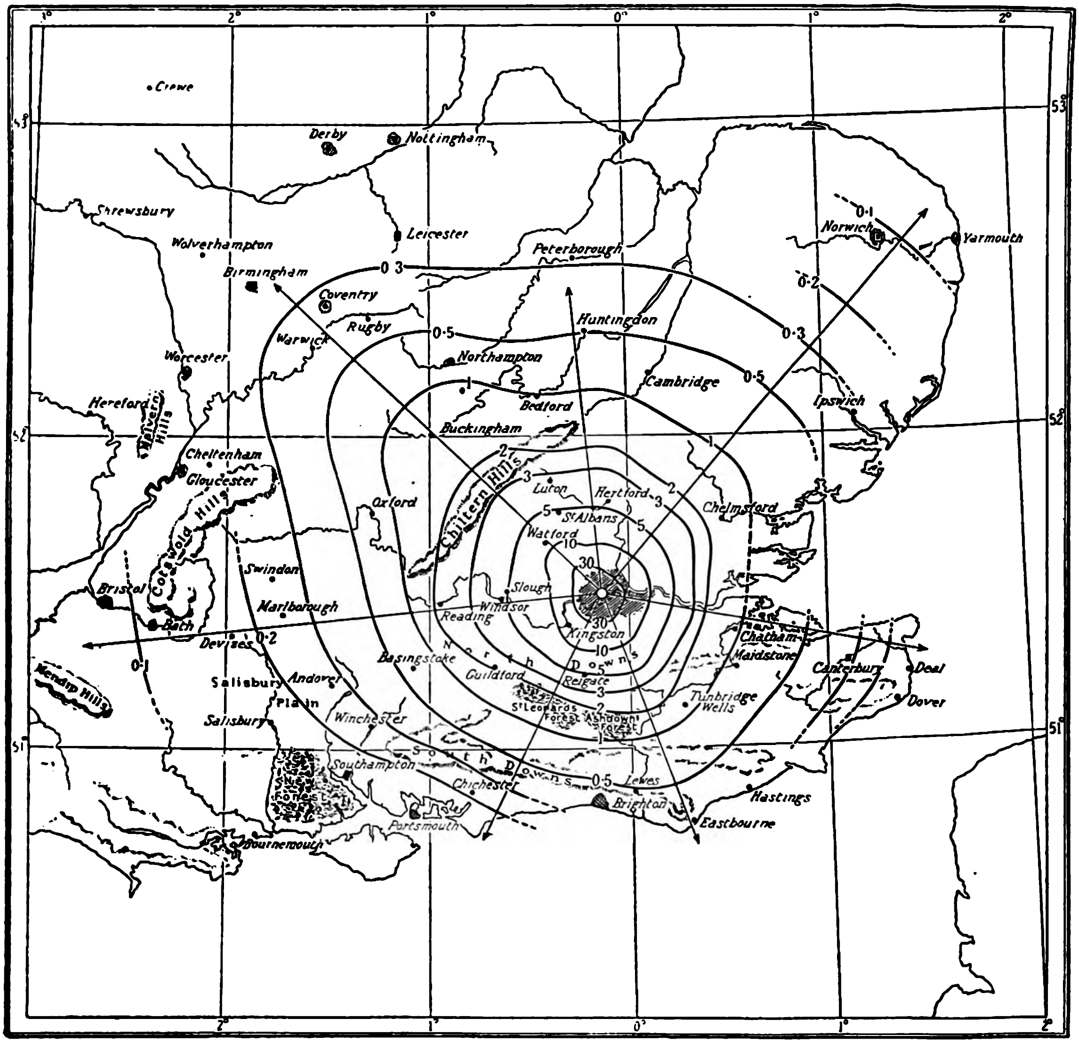


Fig. 7.

While the experimental curves agree well in shape with the theoretical, there still remains to be explained the difference of attenuation with direction and the fact that in all directions attenuation is greater than theory predicts.

It is suggested that the theory does not fit the facts because it assumes a flat surface, and does not take account of objects such as trees, houses and other erections which occur in practice. Messrs. Round, Eckersley, Tremellen and Lunnon have, in fact, already concluded that this was the sole cause of the land attenuation which they observed on longer waves (10—25 km.).

The English countryside is mostly thickly wooded, and trees must contribute an appreciable amount to the surface absorption.

The author then discusses the amount of energy absorbed from a wave by a given tree. The effect of the tree is as shown in Fig. 11, where in (*a*) the magnetic field of the wave is shown by the parallel straight lines H_1, and the secondary field due to the tree by the concentric circles H_2. If the two fields are in phase the resultant will be as in (*b*), the distortion closely resembling that which occurs in the neighbourhood of a wire carrying a current in a uniform magnetic field. The resultant field can be mapped out by a portable direction finder. This was done for several trees, bearings on the apparent direction of 2LO being taken in a number of positions on a circle of approximately 10 feet radius round the tree. A curve can be drawn showing the relation between the angular departure from true bearing and the direction of the line joining the set and the tree with respect to the transmitter. A field distortion of 10 degrees was given by a very large oak tree.

An expression is derived by which the power absorbed by a tree can be evaluated by measuring the error produced on a direction-finding set at a distance d from the tree, in terms of the height of the tree, the distance d and the error in field distortion produced.

The author then quotes Sommerfeld and Bouthillon as showing that a wave must not be regarded as travelling parallel to the surface but rather as incident to the surface at the critical angle of incidence for which the reflected wave vanishes. This is shown in Fig. 14, where the angle θ—corresponding to Brewster's angle in optics—is determined by the frequency and the electrical constants of the earth.

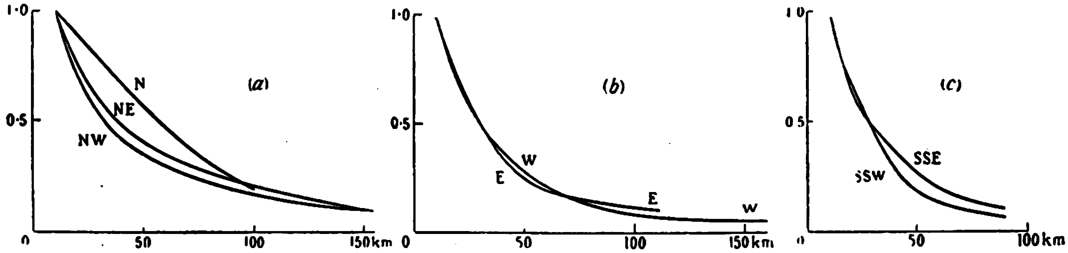


Fig. 8.

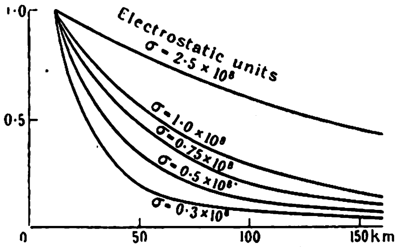


Fig. 9.

For the particular experimental conditions here dealt with, the angle is given by

$$\tan\theta = \left(\sqrt{\frac{2j\sigma}{f}}\right)$$

where a is the conductivity of the earth in electrostatic units, f is the frequency of the waves, and $j = \sqrt{(-1)}$.

Since there is no reflected wave the incident wave must be regarded as passing completely into the earth at this critical angle θ, and it becomes possible to state the rate at which the earth is absorbing energy. It is the amount of energy carried by a wave through a surface inclined at an angle (90 deg.—θ) to the direction of propagation, and is shown to be

$$P_0 = \frac{E^2 \times c}{8\pi} \mid \cos\theta \mid \times 10^{10}$$

where P_0 = power absorbed by earth per km.^{2},

E = field strength of waves, and

$c = 3 \times 10^{10}$ cm. per sec.

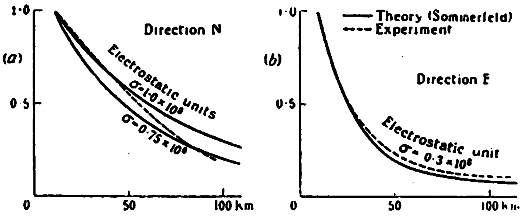


Fig. 10.

From this, an expression is derived showing the number of trees per unit area required to absorb an amount of power equal to that absorbed by the earth, from which expression it is concluded that about 1,600 trees per km.^{2} will have an attenuating effect equal to that of the earth for the particular experimental conditions given.

The equivalent bare surface is that surface devoid of trees, etc., which would absorb the same amount of energy as the surface under consideration, and the author proceeds to derive values of the conductivity of the equivalent surface. The results are shown in Table IV, which shows the effect of trees on the apparent conductivity of the surface for the wavelength under consideration.

Actual counts of the trees in the various districts have been made, showing that the number varies from about 500 per km.^{2} in the least-wooded districts (N. of London) to the 4,000 per km.^{2} in the most densely-wooded parts (S. of London).

It is concluded that the effect of trees may go a long way towards explaining the different apparent conductivities observed in the different directions, and also in causing all the values to be considerably below that of the conductivity as found by other methods. No doubt hedges, other vegetation, houses and other erections contribute to the absorption produced, but it seems probable that trees alone caused the greatly preponderating effect in these particular experiments.

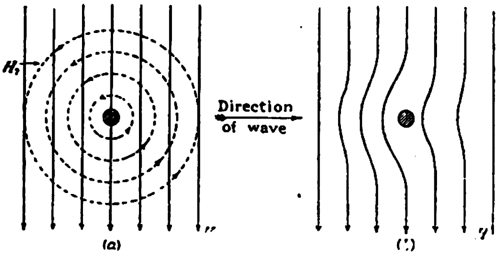


Fig. 11.

Opportunity was taken when it presented itself of making measurements on other wavelengths. Observations were taken on the Birmingham B.B.C. transmitter (475 m.) at a few positions, and on transmissions from the N.P.L., Teddington, on 720 m. The results obtained confirm those of the main experiments.

TABLE IV.

EFFECT OF TREES ON APPARENT SURFACE CONDUCTIVITY.

Number (N) of trees per km.^{2}	σ_1, in E.S.U. (approx.)
0	2.5×10^8*
200	2.0×10^8
500	1.5×10^8
1,000	1.0×10^8
2,000	0.5×10^8
4,000	0.2×10^8
6,000	0.1×10^8

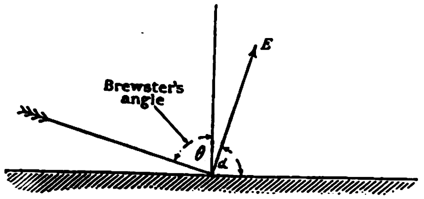


Fig. 14.

The work described was carried out for the Radio Research Board, under the Department of Scientific and Industrial Research.

DISCUSSION.

A lengthy discussion followed the reading of the paper.

The discussion was opened by **Dr. R. L. Smith-Rose** who thought that the paper was a very progressive step towards knowledge of attenuation, a subject which had been neglected for twenty years. Since the early work of Duddell and Taylor, increase in the power of the transmitter and in the sensitiveness of the receiver had diverted attention from it. Its significance had been neglected up to the time of broadcasting, a reliable service of which depended on the surface waves. The paper confirmed the theoretical work of Sommerfeld. Considering the discrepancy of conditions theory, as corrected, agreed with experiment. In his Chairman's address, Col. Lee had referred to the tilt in Scotland being greater than that measured in England. This might be because the ground in Scotland was of lower conductivity and he suggested experiments around a Scottish broadcasting station. He illustrated slides of other contour maps, one around New York district, an air map and contours of New York City showing the local absorption by steel-framed buildings, and a third of the field around the Melbourne (3LO) broadcasting station.

Prof. E. V. Appleton said that the paper was so complete that little criticism was possible. He thought the effect of trees might vary with season, due to variation of the condition of the trees. Had the author calculated the effective resistance of the tree and its reactance as a condenser—that is, compared R with $1/C_p$? Such capacity effect might lead to a process of scattering, which could be judged by whether the minimum was sharp or not.

Mr. R. A. Wilmotte, referring to the contour map of Fig. 7, noted that at certain forests in the south, the curves seemed to be closer in front and farther apart behind the forests. This might be due to reflection or similar effects at the forests. He also discussed the possibility of reflection from the sea coast, quoting the differences shown between Birmingham and the Wash. He suggested investigation of the attenuation due to towns, measurements being made just before and beyond, especially of towns with not many aerials tuned to 2LO.

Mr. Warren said that the paper added considerably to knowledge of the factors governing attenuation. As regards the use of the word itself, attenuation included spreading, diversion, absorption, etc.; the author had dealt with absorption only. Although a value of σ had been found which fitted Sommerfeld's theory, there might be other causes of absorption. He discussed the possibilities of differences of the earth's conductivity at the surface and deeper down. The measurement for tilt was probably different to that for absorption due to this cause. Referring to the use of 10 kms. as a standard (Fig. 8), he thought that differences along separate radial lines up to 10 km. might cause inaccuracy in the ratios employed for the remainder of the line.

---

* Normal value.

Mr. J. E. Taylor thought it expedient to use discretion in making deductions. As to correction for the curvature of the earth's surface, what was the nature of the correction and the ranges to which it was applied ? Regarding the effect of trees as compared with hills, why should one excrescence have a greater effect than another ? Energy passing into the ground was presumably dissipated as an i^2R loss, and the current in the ground would give an external field effectively equivalent to a re-radiation. He also referred to the fact that certain regions had been described as " dead spots " for broadcast reception.

Capt. P. R. Eckersley considered the work interesting to the B.B.C. since broadcasting work depended on the direct ray. A field strength map in Sweden, with a forest on one side and a lake on the other, showed absorption from the forest. Dr. Meissner in Germany considered that the half wavelength aerial gave rise to less attenuation. There were effects in mountainous districts and the shielding effect in valleys was well known. Much difficulty on this account was experienced in the region served by the Cardiff station. The assymetry of radiation from 5GB was apparently due to large masts. The attenuation of 5GB was equal all round, and there were no large forests.

Lt.-Col. H. R. T. Lefroy said that the paper gave confirmation of early military experiences before the war. Taking cover in woods working with portable receivers led to loss of reception. He suggested that the effect of trees was implicit in Dr. Smith-Rose's previous figures for earth conductivity. As regards depth of penetration, this might be important in different conditions of weather.

Lt.-Col. Aston pointed out that in Fig. 7, contours 2 and 3 were close at Gravesend, where the Thames was opening out, and were wider apart between Windsor and Reading where there were certainly more trees than between Chatham and Gravesend.

Lt.-Col. Angwin said that the author excluded all factors save that dealt with in the paper. The New York contour lines in the slide shown (by Dr. Smith-Rose) were less regular and had great differences of gradient. Espenschied attributed this to the density of building. He suggested that different attenuation gradients might be due to the aggregation of houses, aerials, frame structures, etc.

Mr. Barfield briefly replied to several of the points raised in the discussion, leaving more detailed points to be answered in writing.

On the motion of the Chairman (**Lt.-Col. A. G. Lee**) the author was cordially thanked for his paper.

Fire Damage at Ditton Park Research Station.

A serious fire occurred at the Radio Research Station, Ditton Park, near Slough, on 1st December. A 200-foot lattice mast was wrecked and a laboratory building (erected round the mast) and all the apparatus in it were totally destroyed. The damage is estimated at several thousands of pounds. The photograph shows the scene after the fire.

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research

PROPAGATION OF WAVES.

Further Measurements on Wireless Waves received from the Upper Atmosphere.—R. L. Smith-Rose and R. H. Barfield. (*Proc. Roy. Soc.*, 116A, pp. 682-693, November, 1927.)

The paper describes a continuation of work on the analysis of the electromagnetic field of radio waves arriving at a receiving station from the upper atmosphere. The results previously published (*Proc. Roy. Soc.*, A, 107, 587, 1925, and 110, 580, 1926) were confined to measurements on waves received from the Bournemouth transmitting station. In the present paper the investigation is extended to transmissions from three other stations, viz., Birmingham, London and Newcastle.

Measurements are made of the mean angle of incidence of the downcoming waves, and from these the effective height of the ionised layer is calculated. By making use of a knowledge of the attenuation of the surface-wave over land, it has been possible to arrive at values for the coefficient of reflection of the ionised layer for the various cases dealt with.

Suite d'une Etude sur la Propagation des Ondes Courtes (Continuation of an investigation on the propagation of short waves).—M. Lardry. (*L'Onde Electrique*, 6, 70, October, 1927, pp. 465-481.)

Account of a new chapter in the investigation carried on daily since January, 1924, some results of which have already appeared in *L'Onde Electrique* (3, 1924, pp. 254, 449 and 502; and 4, 1925, pp. 355 and 401). The method has been kept the same all through, the intention being to measure, every day at the same time, the signal strength of a transmitter working regularly under the same conditions, and thus to study the anomalies of propagation with the distance constant. The transmission chosen was the daily meteorological bulletin from Casablanca on 51 metres. Advantage was also taken of the voyages of the *Jacques Cartier* (31 metres) across the Atlantic to obtain a general view of the anomalies of propagation as a function of the distance. Very simple apparatus, consisting of a detector with reaction and one low frequency stage, was employed, the aim being to secure stability rather than sensitivity. The observations recorded are shown graphically and discussed. The large variations found in the daily averages are attributed to the lower atmosphere, and the superimposed extremely rapid fluctuations to quite local meteorological phenomena, while it is thought that the long-period variations from year to year, showing perhaps a migratory character, might find their explanation in the upper atmosphere. The "new chapter" refers to the very anomalous reception disclosed last winter, when the Casablanca transmission, instead of increasing in intensity from the autumn onwards as in previous years, had very great difficulty in getting through at all, also markedly abnormal signal strength from the *Jacques Cartier* and other sources was observed. It is hoped that this unanticipated fact will help to throw light on long-period variations extending over one or more years.

Observations pendant l'Eclipse du 29 Juin (Observations during the eclipse of 29th June).—A. Nodon. (*L'Onde Electrique*, 6, 69, p. 460.)

Radio observations were carried out during the partial eclipse at Sauveterre de Béarn (Low Pyrenees), but nothing abnormal was recorded.

Diagramme des Champs Electriques Mesurés à Meudon pendant le Début de l'Année 1926 (Graphs of electric fields measured at Meudon during the first part of 1926).—(*L'Onde Electrique*, 6, 70, October, 1927, pp. 509-511.)

The graphs are reproduced of the U.R.S.I. observations made at Meudon of the fields of Bordeaux, Nantes, Rome and Leafield, for the first five months of 1926. The measurements were carried out by the method described in the first number of *L'Onde Electrique* (January, 1922).

Wave Propagation and the Weather.—F. Charman. (*E.W. & W.E.*, 4, 51, pp. 735-742, December, 1927.)

On the Refraction of Electro-Magnetic Waves in a Spherically Stratified Medium.—T. Y. Baker. (*Phil. Mag.*, 4, 24, pp. 955-980, November, 1927.)

Various considerations are enumerated, all of which make the investigation of the paths of light and wireless waves very complicated, and it is only in hypothetical cases where some of the governing factors are omitted that rigorous mathematical treatment is possible. Such a course is followed in this paper. Nothing but straightforward refraction is considered, that is to say, the waves are supposed to move everywhere at right angles to themselves with velocities inversely proportional to the infractive index, also all diffraction, absorption and surface reflection effects, whether at the earth's surface or possibly at the Heaviside layer, are left out of account. While the investigation aims at showing what kind of physical effects in the reception of wireless signals will be found in this hypothetical atmosphere, no attempt is made to discuss the physical conditions such as density degree of ionisation, etc., at any point that produce the particular refractive index at that point, except that it is assumed that refractive index is a function of wavelength. With these limitations, mathematical investigation is made of the nature of the distribution of refractive index that will allow of a transmission of energy completely round the earth and give rise to wireless phenomena such as the skip distance.

Du Milieu Ethéré (On the ether medium).—L. Garrigue. (*QST Français et Radio Electricité*, 8; 40, 42, 43, 44; pp. 37, 31, 30 and 4 respectively.)

Continuation of the philosophical discussion begun in the June number of *QST Français* (these Abstracts, October, 1927, p. 635). In the July number (40) the author expresses the opinion that the manner of working of the simple toy gyroscope is sufficient proof of the existence of an ether in motion. In the September and two following numbers the article changes its title to "De l'Onde Hertzienne et de sa Propagation" and the Hertzian wave is explained as the result of the impressions of the electron's gyratory movement upon the ether wave.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

La Rèsonance et les Atmosphériques (Resonance and atmospherics).—H. de Bellescize. (*L'Onde Electrique*, 6, 68 and 69, pp. 333-356 and 427-444 respectively.)

The author collects together the views scattered in certain of his previous publications. He regards the different aspects which atmospherics assume as various manifestations of a single phenomenon, namely, the re-establishment of electrical equilibrium in the layers of the atmosphere. The phenomenon is always taking place and is in no sense localised. When it is said that there are no atmospherics, it means simply that at that time their level is momentarily dominated by the signal. The practically continuous discharges, that may or may not be accompanied by luminous manifestation, with multiple nuances due to chance, present a continuous or subdivided appearance according to their amplitude and the distance at which they are observed, the density of the successive shocks varies inversely as their amplitudes and a sufficient increase of the sensitivity of the receiver always leads to recovering the level of the disturbances. This point of view is supported by the experiment consisting of listening to signals, subject to fading, with a receiver provided with a device automatically varying the sensitivity inversely as the signal intensity, when complete calm and more or less violent disturbance alternate with one another at the caprice of the fading. A bibliography is appended.

Système Antiparasite Marrec (The Marrec system for eliminating atmospherics).—Y. Marrec. (*L'Onde Electrique*, 6, 70, October, 1927, pp. 501-508.)

Paper read before a meeting of the S.A.T.S.F., 10th May 1927. After recalling the principal means that have been employed to protect radio communications from atmospheric disturbances: resonance effects, beats, high and low frequency differential systems, limitation of amplitude; the author examines the action of atmospherics on these different systems, and gives his opinion as to the reasons for their failure. He then describes the Marrec filter, with experimental demonstrations of its effectiveness. The discussion after the reading of the paper is reproduced.

Atmospherics and Transatlantic Telephony.—A. G. Lee. (*Electrician*, 11th November, 1927, pp. 588-590.)

Extracts from the inaugural address to the Wireless Section of the I.E.E., delivered on 2nd November.

An abstract of the address is also to be found in *E.W. & W.E.* for December, pp. 757-759.

The Electrostatics of the Thunderstorm.—A. W. Simon. (*Journ. Franklin Inst.*, 204, 5, pp. 617-647.

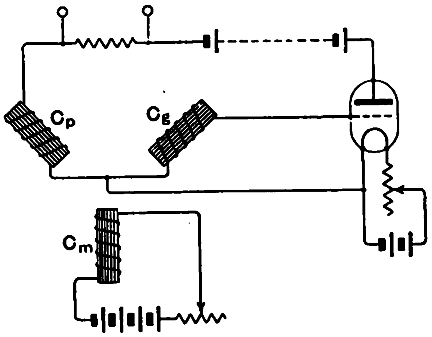
The Fields of Force in the Atmosphere of the Sun.—A. Buss. (*Nature*, 12th November, 1927, p. 693.)

A letter referring to M. Deslandre's recent communications in *Compte Rendus* and *Nature* on the constitution of the sun.

PROPERTIES OF CIRCUITS.

Theory of the Valve Maintained Vibrating System.—S. Jimbo. (*Journ. Inst. Elect. Eng. Japan*, No. 469, pp. 856-859.)

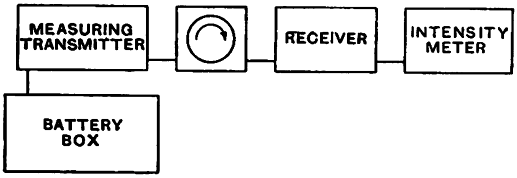
The principle is explained of a new kind of valve-maintained vibrating system, in which the frequency is very steady and also adjustable. The device is the combination of a valve and a mechanically vibrating system which is electro-magnetically coupled with the valve circuit and an inductive coil excited by D.C., as shown below.



Ein Beitrag zur Quantitativen Messung von Empfängern (Contribution to the quantitative measurement of receivers).—E. Klotz. (*Telefunken-Zeitung*, 8, 45/46, pp. 54-64.)

Description of apparatus developed and employed in the Telefunken laboratories for testing wireless receivers. In the arrangement the distant transmitter is replaced by an auxiliary transmitter, close to the receiver, connected through a calibrated coupling adjustment, the outgoing currents being measured with a special instrument, as shown below.

The transmitter furnishes alternating tension that can be varied in its effective value from 1—3,000,000, where the smallest value to which it can be adjusted is .005 microvolt. The tension can be altered between 3.10^6 and 15.10^{-8} periods and in addition is modulated by note frequency.



The degree of modulation can be chosen between 0 and 100 per cent. The indicating intensity meter shows tensions between .02 and 100V. Its calibration is frequency-constant and, within wide limits, independent of the running conditions. The use of the apparatus is shown by means of an example.

ON FREQUENCY VARIATIONS OF THE TRIODE OSCILLATOR.—D. Martyn. (*Phil. Mag.*, 4, 24, pp. 922-942, November, 1927.)

Frequency variations due to changes in filament current, plate voltage, and coupling are investigated experimentally. Variations as great as two octaves or more are described. The most important cause of frequency variations is found to be the flow of grid current. The conditions for maximum and for minimum frequency change are worked out. The experimental results are then explained in detail by means of the theory.

ON THE VALUES AND THE EFFECTS OF STRAY CAPACITIES IN RESISTANCE-COUPLED AMPLIFIERS.—M. von Ardenne and W. Stoff. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 895-901.)

The general theory of stray capacities is first developed with due consideration of the phase conditions, and then the values and effects of stray capacities are discussed for a three-stage amplifier of practical dimensions.

THE SHORT WAVE LIMIT OF VACUUM TUBE OSCILLATORS.—C. R. Englund. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 914-927.)

An investigation of the short wave limit of valve oscillators of the normal type, where regeneration builds up oscillations in a resonant circuit, indicates that the physical limits for ordinary commercial valves lie between 3.5 and 1.5 metres, depending on the type of valve used. By means of a small special valve a wavelength of 1.05 metres was reached. No frequency control was left at this wavelength. With a small power valve not deviating greatly from ordinary vacuum construction, it was possible to operate at 3.5 metres with adequate frequency control, and it is concluded that the 3.5—5 metre range is available for technical purposes. Apparatus for measuring wavelength is discussed together with its application to the measurement of capacity and inductance. A bibliography of short wave valve oscillator work is attached.

THE SUPPRESSION OF PARASITIC OSCILLATIONS IN VALVE CIRCUITS.—M. Reed. (*E.W. & W.E.*, 4, 51, pp. 725-732, December, 1927.)

A GRAPHICAL METHOD OF AMPLIFIER COUPLING DESIGN.—M. G. Scroggie. (*E.W. & W.E.*, 4, 51, pp. 733-734, December, 1927.)

VOLTAGE DETECTION COEFFICIENT.—E. L. Chaffee. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 946-957.)

The advantages of the use of voltage detection coefficient as a means of expressing the sensitivity of a detector and for the comparison of detectors are discussed. An experimental method is given for the measurement of the fictitious equivalent audio voltage which, if acting in the plate circuit of a detector, would give the demodulated audio plate current. Some experimental results are given for both plate-circuit detection and grid-circuit detection. The experimental results show that a high-μ tube is usually more sensitive as a detector than a low-μ tube.

RESONANT CIRCUITS WITH REACTIVE COUPLING.—R. T. Beatty. (*Phil. Mag.*, 4, 25, pp. 1081-1098, November, 1927.)

A mathematical paper considering linear fundamental equations with constant coefficients, so that the discussion is limited to the subject of amplification over a linear region of the characteristic curve and under conditions where the grid current is negligible: that is, the amplification is without distortion. The problem is simplified without using approximations by the introduction of equivalent circuits, and a representation by means of curves derived from a parabola is given, by help of which the behaviour of the circuits can be ascertained by inspection.

The geometry of the parabola is used to facilitate the discussion of amplification and resonance curves, and an attempt is made to give a quantitative basis for the treatment of selectivity by the introduction of two new terms—" tolerance " and " activity."

The results so far obtained are summarised in a table. With regard to the reception of broadcasting, it is found that selectivity is best achieved with symmetrical circuits and no reaction, provided that sufficient amplification can be obtained.

MAKING NORMAL CO-ORDINATES COINCIDE WITH THE MESHES OF AN ELECTRICAL NETWORK.—E. A. Guillemin. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 935-945.)

The theory of normal co-ordinates in oscillatory systems is briefly reviewed, and their significance in connection with the electrical network pointed out. The relation which must hold between the circuit constants in order that normal co-ordinates may be made to coincide with certain meshes is derived. The effect of having made a certain mesh a normal co-ordinate of the system is then shown for the transient state, first, to confine the corresponding normal frequency to that mesh; secondly, to cause its amplitude to be independent of the other circuit constants; and thirdly, to cause that normal frequency to remain inactive unless the actuating E.M.F. is impressed in that mesh. The effect so far as the steady state is concerned, is to confine resonance with the normal frequency in question to the normal mesh, and in general to present a means for eliminating or localising resonance peaks in more complicated networks.

Quelques Expériences avec des Triodes et les Oscillations de Relaxation (Some experiments with valves and relaxation oscillations).—B. van der Pol and J. van der Mark. (*L'Onde Electrique*, 6, 69, pp. 461-464.)

Au Sujet d'une Méthode Simple de Calcul de l'Inductance de Modulation (On the subject of a simple method of calculating the modulation inductance.)—C. Krulisz. (*L'Onde Electrique*, 6, 69, p. 464.)

Referring to his article of this title in *L'Onde Electrique* for June, 1927, pp. 255-262, Commandant Krulisz writes that the internal resistance ρm of the generating valve was there taken as equal to the "static" resistance of the valve, just in order to simplify the problem, but he here points out that this is only correct when the valve works on the straight part of its characteristic curve, which is not the case in the majority of practical applications. Actually, the "dynamic" resistance of a generating valve working with good efficiency is smaller, but this fact does not introduce any alteration in the aspect of the calculations. From a quantitative point of view, greater values for the inductance are demanded for a given problem.

The value of the "dynamic" resistance is being thoroughly investigated by M. J. Groszkowski at Warsaw.

Contribution à l'Etude de la Basse Fréquence (Contribution to the study of low frequency).—M. Dupont. (*QST Français et Radio Electricité Réunis*, 8, 44, pp. 13-18.)

An article in two parts dealing firstly with the characteristics of valves and applications, and secondly with connecting transformers.

Supers et M.F. (Superheterodynes and Medium Frequency).—J. Vivié. (*QST Français et Radio Electricité*, 8, 42, pp. 17-25.)

First instalment of a serial article on superheterodynes and intermediate frequency amplification.

Les Neutrodynes.—S. Lwoff. (*QST Français et Radio Electricité*, 8, 44, pp. 56-62, November, 1927.)

Concluding instalment of a serial article on neutrodyne theory and practice begun in the September number of last year.

TRANSMISSION.

The New York-London Telephone Circuit.—S. B. Wright and H. C. Silent. (*Bell System Technical Journal*, 6, 4, October, 1927, pp. 736-749.)

Discussion of the special provisions in use on the transatlantic telephone to compensate for the variability of the wire and ether paths, for the radio noise, and for the fact that two-way transmission is effected upon a single wavelength. So-called technical operators are in attendance at each end of the radio path and are equipped to adjust the magnitude of the speech currents entering the radio transmitters to such a value as to load these transmitters to capacity. The amplification introduced at the radio receivers can also be adjusted to compensate for changes in the transmission efficiency of the radio paths. Finally, voice-operated relays together with suitable delay circuits are provided which so control the apparatus that at any given time it can transmit in but one direction. By this arrangement, a speaker's voice upon leaving his transmitting station cannot operate his own receiver although this is tuned to the transmitting wavelength.

Les Antennes d'Emission (Transmitting antennæ)—M. A. Cremailh. (*QST Français et Radio Electricité Réunis*, 8; 38, 41 and 43; pp. 21, 45 and 60 respectively.)

A theoretical and experimental study of the construction, operation, and means of obtaining optimum radiation, of the majority of possible antenna types.

Ein Röhrengenerator zur Erzeugung von modulierter Hochfrequenz für Laboratoriumszwecke (A valve transmitter for the production of modulated high frequency for laboratory purposes). — F. Gabriel. (*Elekt. Nachr. Technik.*, 4, 10, October, 1927, pp. 426-434.)

Description of a three-valve generator containing one control valve, one transmitting and one modulating. For the control valve's self-exciting circuit, the dynatron arrangement is chosen as being the simplest means of obtaining perfectly sinusoidal oscillations and freedom from reaction. The principle is shown in Fig. 1.

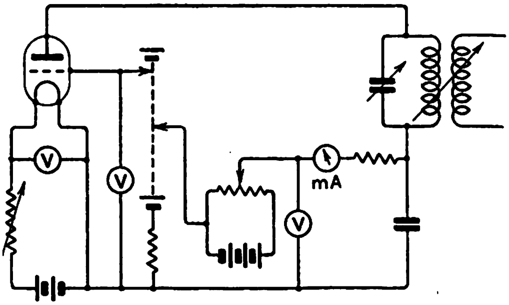


Fig. 1.

The transmitting and modulating valves are connected up in a circle, as represented in Fig. 2, the arrangement being very convenient for observing the degree of modulation. To high frequency the circle is barred by means of choke coils and a special circuit opened which is inaccessible to low frequency.

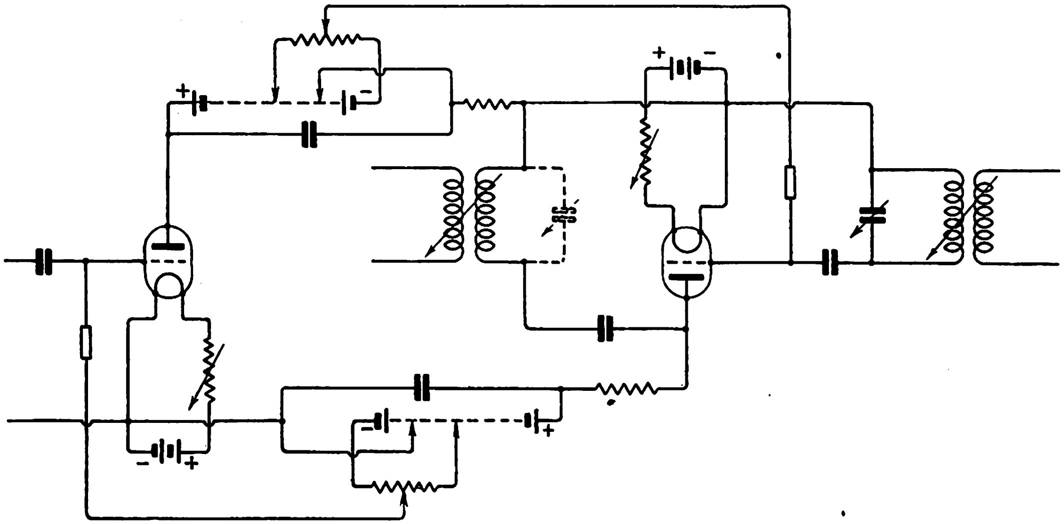


Fig. 2.

Some Experiments with Side-Band Telephony on Short Wavelengths.—E. Howard Robinson. (*E.W. & W.E.*, 4, 51, pp. 715-721, December, 1927.)

Calcul des Constantes Electriques et Mécaniques des Antennes Pseudo-symétriques avec Application aux Antennes genre FL (Calculation of the electrical and mechanical constants of pseudo-symmetrical antennæ, with application to antennæ of the FL type.)—M. Stern. (*L'Onde Electrique*, 6, 70, October, 1927, pp. 482-500.)

Concluding part of an article begun in *L'Onde Electrique* for July, of which a brief summary was given in these Abstracts for November, p. 695.

RECEPTION.

The Problem of Selectivity.—A. Castellain. (*Wireless World*, 9th November, 1927, pp. 649-651.)

An article intended to show as simply as possible on what factors selectivity of tuning depends and how it is connected with the problem of good quality reproduction.

Automatic Volume Control.—(*Wireless World*, 23rd November, 1927, pp. 719-720.)

Abstract of a paper by Mr. Harold A. Wheeler, read before the Institute of Radio Engineers on 2nd November, 1927, constituting an important contribution to the technique of broadcast reception. Compensation for changes of signal strength due to fading is obtained with negligible time lag and without making use of relays or moving parts.

A Plea for Choke-Coupling.—A. L. Sowerby. (*Wireless World*, 9th November, 1927, pp. 641-642.)

Mauvaise Réception en Radiophonie (Faulty broadcast reception).—R. Braillard. (*QST Français et Radio Electricité Réunis*, 8, 40, pp. 48-53.)

A lecture given to the Société Belge des Electriciens, at Brussels, 26th February, 1927, discussing the causes and remedies for poor broadcast reception.

Sur les Contacts Imparfaits (On imperfect contacts).—H. Pélabon. (*L'Onde Electrique*, 6, 69, pp. 401-426.)

The author describes the apparatus he has employed to vary automatically the distance between the two parts of a detector, or the pressure they exert on one another, in a continuous manner. He first studies the system galena-steel with both direct and alternating current and as a detector, and finds that two kinds of rectification (interior and exterior) exist for all contacts formed by a metal and a semi-conductor, and is led to insist on the part played by thermoelectric phenomena and coherence. Purely metallic contacts, for which there is only a single rectification, are then considered, including the system steel-steel, the article terminating with a brief discussion of the theory of the two contact resistances (*cf.* these Abstracts June, November and December, 1926, pp. 386, 703 and 770 respectively, and June, 1927, p. 372).

VALVES AND THERMIONICS.

THE VALVE FILAMENT AT CONSTANT VOLTAGE.—E. H. Banner. (*Journ. Sci. Instr.*, 4, 10 and 11, 1927, pp. 317 and 349 respectively.)

Description of experimental work continuing that done at Birmingham in 1924 (*Proc. I.R.E.*, 14, 325). The primary object of the work was an experimental investigation of the term "constant filament current" or voltage, for standard tests.

When the filament of a thermionic valve emits and a thermionic current flows from the filament to the anode and through an external circuit back to the filament, the filament current is necessarily different at all points along the filament. An ammeter in each filament lead and a voltmeter across them will all read differently when the valve emits, the actual deviations depending on the electronic emission and the circuit used. The only exceptions are the case of a filament connected directly to a source of P.D. with no intermediate rheostat, when the voltage will be maintained constant by the supply, but the currents will vary in any case. The other exception is that of the valve with the separately heated cathode, the potential of which is uniform.

The variations of the reading of the filament voltmeter and ammeters have been investigated experimentally, and a circuit has been devised in which there is no change of reading of the voltmeter or either ammeter when the anode current is switched on and off. The current read is the filament battery current, and with this circuit tests may be repeated on valves with the certainty of the filament conditions being constant for different tests.

An investigation was also made of the validity of the practice of readjusting the filament voltage after switching on the anode potential, and it was found that this practice is not correct as regards maintaining the filament under constant conditions, except for those valves intended to be run without a rheostat.

NEW USES FOR VALVES.—A. Dinsdale. (*Wireless World*, 9th November, 1927, pp. 643-645.)

Account of the employment of valves in power stations to control A.C. and D.C. generators.

THE NEW COSMOS A.C. VALVE.—*Wireless World*, 23rd November, 1927, pp. 713-714.)

Brief account of this power output valve of excellent characteristics with indirectly heated cathode, the necessary emission being obtained from a long, fine nickel tube coated with a mixture of barium and strontium oxides, enclosing the heater in the form of a hairpin filament, and insulated from it by a layer of porcelain. The consumption is one ampere at four volts.

A NOTE ON THE THERMIONIC WORK FUNCTION OF TUNGSTEN.—C. Davisson and L. Germer. (*Physical Review*, 30, 5, pp. 634-638, November, 1927.)

The authors correct their measurements upon the thermionic work function of tungsten (*Phys. Rev.*, 20, 300, 1922) for the "Schottky effect"—that is, for the reduction of the work function by the external electric field at the surface of the filament; and also they take occasion to discuss the interpretation of their work function measurements rather more fully than in the original paper.

DIRECTIONAL WIRELESS.

DIRECTIONAL WIRELESS AS AN AID TO NAVIGATION.—R. L. Smith-Rose. (*Nature*, 26th November, 1927, pp. 774-776.)

A survey of the subject, which may be divided into two parts, according as the directive characteristic is applied at the transmitting or the receiving end of the wireless link. The latter case is considered first and the directional receiver or direction-finder is discussed, with its accuracy, position (whether on shore or board ship), and the conditions for freedom from night errors; and a brief account is given of fixed beacon stations. The second part on directional transmission is divided into three sections, dealing respectively with the beam system as installed at Inchkeith and South Foreland, rotating loops, and course setters.

DIRECTIONAL RADIATION WITH HORIZONTAL ANTENNAS.—A. Meissner. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 928-934.)

A translation into English of the paper appearing in *Zeitschrift für Hochfrequenz.*, 30, 3, 77-79, September, 1927 (these Abstracts, December, 1927, p. 766).

MEASUREMENTS AND STANDARDS.

PIEZO-ELECTRIC OSCILLATORS AND PIEZO-ELECTRIC FREQUENCY STABILIZERS.—Y. Watanabe. (*Journ. Inst. Elect. Eng. Japan*, No. 469, August, 1927, pp. 835-855.)

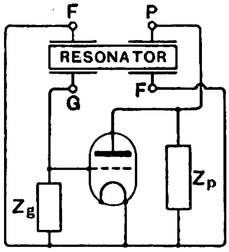
From the point of view of self-oscillating action, piezo-electric oscillators may be divided into three classes: when the regenerative coupling between plate and grid of the valve is due to the

(1) coupling action given by the piezo-electric coupler as in Fig. 1.

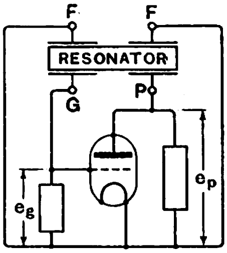
(2) regenerative coupling by means of the piezo-electric resonator, and as in Fig. 2.

(3) and simply to the "pulling into step" characteristics of the valve amplifier.

Each class of oscillator is considered, particularly with regard to the conditions for building up oscillation, and some experimental results are given for verification.



(a)



(b)

The frequency stabilising action of the valve oscillator by means of the piezo-electric resonator may be explained by the well-known characteristics of "Zieherscheinungen" which take place in the coupled circuit valve oscillator. Although the natural frequency of the electrical oscillation circuit of the oscillator may be pretty widely changed, the frequency of the oscillation can be stabilised at a nearly constant value by means of the piezo-electric resonator, which behaves as the statically coupled secondary oscillation circuit, the natural frequency of which is constant. This coupled circuit, including the resonator, may be easily represented in the form of an equivalent electrically coupled circuit by taking into consideration the motional admittance of the resonator. Consequently the observation of the frequency characteristic near the resonance point enables us to determine the equivalent electric constants of the piezo-electric resonator. The great effectiveness of the stabilising action of the resonator is shown by some experimental results and compared with the electric method for obtaining constant frequency.

Mounting Quartz Oscillator Crystals.—R. C. Hitchcock. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 902-913.)

Various types of mountings are described for quartz oscillator crystals having frequencies in the vicinity of one million cycles per second. For low power work a spaced upper electrode is recommended, mounted in a neon-filled tube. For radiating up to 50 watts from the crystal-controlled tube, a similar mounting placed in a copper-based tube is advised. This latter tube can be cooled by immersion in an oil bath. Accurate temperature control of the oil bath keeps the radio frequency within narrow limits.

On the Use of the Electromagnetic Receiver in Acoustical Measurements. — T. S. Littler. (*Journ. Sci. Instr.*, 4, 11, pp. 337-341)

The advantages of the electromagnetic receiver as a microphone in sound measurements are discussed. It is pointed out that the sensitiveness of the moving-coil receiver is much more constant than that of the moving-iron variety, reasons for which are given. A modification of the usual type of receiver is described, the instrument being rendered sensitive and selective by the use of a tuned electrical circuit, and an arrangement is also given by means of which errors, due to stray electromagnetic disturbances, can be eliminated.

A Radio Signal-Intensity Recorder.—B. Saltmarsh. (*E.W. & W.E.*, 4, 51, pp. 743-745, December, 1927.)

Description of a Valve Wavemeter with Range of 10 Metres to 20,000 Metres.—F. M. Colebrook. (*E.W. & W.E.*, 4, 51, pp. 722-724, December, 1927.)

Description of a valve oscillator wavemeter which is an improvement on the previous design described in the *Wireless World* of 6th October, 1926.

Notes on the Accuracy of Variable Air Condensers for Wavemeters.—W. H. Griffiths. (*E.W. & W.E.*, 4, 51, pp. 754-757, December, 1927.)

L'Etalonnage Absolu des Ondemètres (Absolute calibration of wavemeters).—P. Olivet. (*QST Francais et Radio Electricité Réunis*, 8, 42, pp. 6-13.)

The author reviews in succession three methods of calibration employed in practice: multivibrator, quartz plate, and Lecher wires, dealing more in detail with the last method.

SUBSIDIARY APPARATUS.

A Vacuum Tube Potentiometer.—A. L. Fitch. (*Journ. Opt. Soc. Amer. and Rev. Sci. Instr.*, 14, 4, pp. 348-353.)

In his book "The Thermionic Vacuum Tube" Van der Bijl discusses a circuit which with suitable modifications becomes one of the most versatile of electrical measuring circuits. He uses it to measure the amplifying power of valves under varying conditions. As modified, it is essentially a valve voltmeter circuit and may be used wherever electrical quantities can be measured by equating potential drops. The circuit is shown below:—

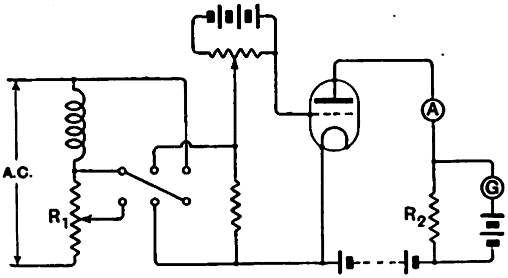


Fig. 1.

A second form of the circuit with two valves has been devised, which does away with the necessity of throwing a switch to and fro. This paper discusses the circuits and the uses to which they may be put in an electrical measurements laboratory.

Exponential Loud-Speaker Horns.—A. Dinsdale. (*Wireless World*, 16th and 23rd November, 1927, pp. 664 and 705 respectively.)

An Application of the Vacuum Tube Oscillator.—C. B. Crofutt. (*Journ. Opt. Soc. Amer. and Rev. Sci. Instr.*, 14, 5, pp. 431-432.)

Account of the use of the valve oscillator to obtain a sustained source of sound, frequently desirable in lecture or laboratory experiments.

Metal Rectifiers. (*Electrician*, 18th November, 1927, p. 626.)

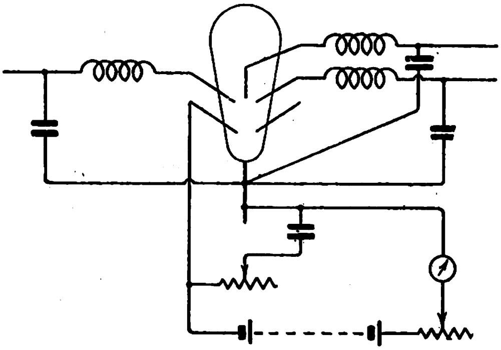
Description of a new rectifier depending for its operation on electronic action at a permanent junction between a copper disc and a layer of cuprous oxide formed upon one face of it. The rectifying effect depends on the fact that the ratio of the resistance from the copper to the oxide coating is very high compared with the resistance from the oxide coating to the copper. Many applications of the device are suggested.

There is also an account of this rectifier and its applications in the *Electrical Review* of 11th November, 1927, pp. 833-834.

The principle on which the rectifier operates is the same as that described by Prof. Sheldon in the *Scientific American* of September, 1926 (these Abstracts, December, 1926, p. 771).

Über die Beseitungen der Hochfrequenzstörungen, hervorgerufen durch einen Quecksilberdampf-Gleichrichter (On the elimination of the high-frequency disturbances produced by a mercury vapour rectifier).—G. Leithäuser. (*Elekt. Nachr. Technik*, 4, 10, October, 1927, pp. 434-435.)

A mercury vapour rectifier was obtained for the high power station at Norddeich for charging an amplifier battery the charging tension of which amounted to about 650 volts. After the rectifier had been constructed and installed it was found that the disturbances were far greater than had been expected and reception was absolutely impossible. A systematic investigation to do away with the disturbances had, therefore, to be undertaken, which is described here. Freedom from disturbance was finally obtained by a judicious insertion of condensers, as shown in the diagram below of the circuit-arrangement ultimately developed.



GENERAL PHYSICAL ARTICLES.

Der selbsttönende Kristall als thermischer Effekt (The spontaneously singing crystal as a thermal effect).—F. Seidl. (*Annalen der Physik*, 84, 19, pp. 384-394.)

A paper referring to that of K. Lichtenecker (*Zeits. f. techn. Physik*, 8, 4, pp. 161-163) in which he opposes the views expressed by the writer in a previous paper (*Phys. Zeitschr.*, 27, 64 and 816) and attributes the phenomenon of the spontaneously singing crystal not to the electromagnetic oscillations but to the steep temperature gradient occurring at the metal point. The writer here gives evidence for believing that both electromagnetic and acoustical oscillations originate in the layer of gas at the point of contact, the many resemblances between the spontaneously singing crystal and the spontaneously singing arc suggesting the possibility that the crystal phenomenon is due to a microscopically small arc or other discharge. The writer intends making further experiments which, it is hoped, will give a final answer to the question.

The Determination of the Elastic Moduli of the Piezo-Electric Crystal Rochelle Salt by a Statical Method.—W. Mandell. (*Proc. Roy. Soc.*, A, 116, pp. 623-636, November, 1927.)

Rochelle salt, which is a double tartrate of sodium and potassium, having the formula $NaKC_4H_4O_6$, $4H_2O$, possesses far larger piezo-electric properties than any other known substance. Whereas the greater of the two piezo-electric moduli of quartz is 0.0677 E.S.U. per kilogram, a usual cuuve for Rochelle salt is 10 E.S.U., and this can be increased to 200 E.S.U. per kilogram for crystals grown in a special manner so as to develop a composite structure. Since this piezo-electric effect is associated only with crystals having an asymmetric structure and occurs when the crystal is submitted to mechanical stresses, it is likely that the phenomenon may be closely related to its elastic properties, and experiments were devised to measure the elastic moduli, the theory and results of which are given here. A further experiment was made to find the variation in elasticity with change of temperature, but no discontinuity was found near the critical temperature of 23° C., when the piezo-electric effect almost abruptly disappears.

The Temperature Variation of the Elasticity of Rochelle Salt.—E. P. Harrison. (*Nature*, 26th November, 1927, p. 770.)

A letter referring to that of Mr. Morgan Davies on this subject in *Nature* of 3rd September, p. 332 (these Abstracts, November, 1927, p. 701), stating that it recalls the analogy between piezo-electric phenomena and the reciprocal relations between strain and magnetic properties shown by ferromagnetic metals, in particular the stationary value in Young's modulus-temperature curve for nickel at about 400° C., the Curie point for that material. The writer adds that a close examination of the temperature variation of the thermal expansion of a piezo-electric crystal would be expected to reveal a discontinuity at the temperature of abrupt change in the piezo-electric modulus which, if present, would be analogous to that found by him in the thermal expansion of nickel.

Photo-Electric Conduction in Selenium.—R. J. Piersol. (*Physical Review*, 30, 5, pp. 664-672.)

Description of experiments leading to the conclusion that the photo-conduction in selenium is due to a photo-electric liberation of electrons rather than to an allotropic change from an insulating to a conducting form of selenium, and that the mechanism of the current conduction under dark conditions is entirely different from that of the photo-conduction.

Photo-electric Effect and Surface Structure in Zinc Single Crystals.—E. Linder. (*Physical Review*, 30, 5, pp. 649-655.)

A paper dealing with an experiment in which the photo-electric current from different parts of the surface of a single crystal of zinc was measured. From the results it appears that photo-electric emission depends upon the orientation of the crystal lattice in the emitting surface. Maximum current was obtained when the hexagonal axis was normal to the illuminated surface and minimum when it was parallel, the ratio being about 2 : 1.

THE RELATION BETWEEN REFRACTIVE INDEX AND DENSITY.—D. Burnett. (*Camb. Phil. Soc. Proc.*, 28, 8, pp. 907-911, October, 1927.)

IONISATION BY COLLISION.—L. G. Huxley. (*Phil. Mag.*, 4, 24, pp. 899-902, November, 1927.)

In this Journal for September, p. 505, J. Taylor gives a reply to the author's remarks on his "Photoelectric Theory of Sparking" in the author's communication entitled "Ionisation by Collision" (*Phil. Mag.* for May), and, in addition, he also raises objections to the Theory of Sparking formulated by Townsend. The intention of the present paper is to consider these objections and comment on the replies.

A DIFFERENTIAL RETARDING POTENTIAL METHOD FOR THE STUDY OF THE ENERGY DISTRIBUTION OF SLOW ELECTRIC EMISSIONS.—C. F. Sharman. (*Camb. Phil. Soc. Proc.*, 28, 8, pp. 922-929, October, 1927.)

INTEGRAPH SOLUTION OF DIFFERENTIAL EQUATIONS.—V. Bush and H. Hazen. (*Journ. Franklin Institute*, 204, 5, pp. 575-615, November, 1927.)

In a previous paper (this Journal, January, 1927) a continuously recording integraph was described, by means of which differential equations, involving only one integration, could be solved. The present paper describes a revision of this machine such that an equation involving two successive integrations, corresponding to practically any second-order total differential equation, with all terminal conditions included, can be solved.

ON MAXWELL'S STRESS, AND ITS TIME RATE OF VARIATION.—S. R. Milner. (*Phil. Mag.*, 4, 24, pp. 943-949, November, 1927.)

ON ELECTRIC PHENOMENA IN GRAVITATIONAL FIELDS.—E. T. Whittaker. (*Proc. Roy. Soc.*, A, 116, pp. 720-735, November, 1927.)

CONTEMPORARY ADVANCES IN PHYSICS. XIV.—INTRODUCTION TO WAVE-MECHANICS.—K. Darrow. (*Bell System Technical Journal*, 6, 4, October, 1927, pp. 653-701.)

DYNAMICAL AND ELECTRICAL PROBLEMS WHOSE SOLUTIONS SATISFY SCHRÖDINGER'S WAVE EQUATION.—A. Bramley. (*Journ. Franklin Inst.*, 204, 5, pp. 561-574, November, 1927.)

UNIDIRECTIONAL QUANTA IN WAVE MECHANICS.—G. Breit. (*Journ. Opt. Soc. Amer. and Rev. Sci. Instr.*, 14, 5, pp. 374-380.)

The problem of emission by an atom is treated according to Schrödinger's rules. The translational motion of the atom as a whole is taken into account. The charge-current density vector is shown to be propagating with the velocity of light in the direction of the emitted quantum. Only unidirectional quanta can be emitted according to the theory. The reason is that the charge-current wave radiates infinitely more intensely if it travels with light velocity than otherwise.

MISCELLANEOUS.

RADIO VISION.—C. Francis Jenkins. (*Proc. Inst. Radio Engineers*, 15, 11, pp. 958-964.)

The writer outlines his method of radio vision and states that, while seeing by radio what is actually happening at a distant place is now an accomplished scientific attainment, the mechanism is not yet a merchandising development, though he confidently believes the completion of a radio vision receiver acceptable to the public is the work of but a few months more.

TELEVISION.—H. E. Ives. (*Bell System Technical Journal*, 6, 4, October, 1927, pp. 551-559.)

Discussion of the chief problems presented in the accomplishment of television, namely: the resolution of the scene into a series of electrical signals of adequate intensity for transmission, the provision of a transmission channel capable of transmitting a wide band of frequencies without distortion, means for utilising the transmitted signals to re-create the image in a form suitable for viewing by one or more observers, and arrangements for the accurate synchronisation of the apparatus at the two ends of the transmission channel.

THE PRODUCTION AND UTILISATION OF TELEVISION SIGNALS.—F. Gray, J. Horton and R. Mathes. (*Bell System Technical Journal*, 6, 4, October, 1927, pp. 560-603.)

A well-illustrated article in three sections, dealing respectively with the apparatus for the analysis and synthesis of the image, the television signal wave, and the terminal circuits for sending and receiving television signals.

SYNCHRONISATION OF TELEVISION.—H. M. Stoller and E. R. Morton. (*Bell System Technical Journal*, 6, 4, October, 1927, pp. 604-615.)

RADIO TRANSMISSION SYSTEM FOR TELEVISION.—E. L. Nelson. (*Bell System Technical Journal*, 6, 4, October, 1927, pp. 633-652.)

Starting from the general requirements imposed on the transmitting medium, this paper discusses the engineering of a radio system for television purposes and describes the radio facilities actually employed for the recent Bell System demonstration. The tests to which the system was submitted to determine its suitability are outlined and the measured frequency-response characteristics shown. An interesting phenomenon due to multi-path transmission, the production of positive and negative secondary images, is reported. A brief series of experiments concerned with the transmission of both voice and image "on a single wavelength" is also described.

VALVE AMPLIFIERS FOR SUBMARINE CABLES.—A. M. Curtis. (*Electrician*, 18th November, 1927, pp. 620-621.)

A paper intended to point out the requirements of cable amplifiers, particularly those used on high-speed loaded cables, and to describe how these requirements have been met in the present signal-shaping amplifier of the Western Electric Co.

Radio—An Aid to Improving Service.—L. Beckwith. (*Electrical World*, 15th October, 1927, p. 595.)

Radio aids in improving electric service by indicating the location of faulty equipment. Experience has shown that a radio-frequency disturbance invariably exists in the vicinity of a piece of electrical equipment for sometime previous to its complete failure ; this condition is particularly noticeable on equipment used with distribution voltages, where radio-frequency disturbances have been known to precede the failure of a piece of equipment for as long a period as several months.

League of Nations.—*Electrical Review*, 11th November, 1927, p. 820.)

In view of the need felt by the League of Nations for the possession of further communication facilities, it is announced that the Board of the Swiss Marconi Company has decided to install a new high-speed radio-telegraph transmitter with an anode power of 50 kilowatts. The range of the installation will be over 3,000 kilometres, so that the station will be capable at any moment of linking-up the headquarters of the League with any place in Europe, the Far East, and North Africa. The present transmitters will be reinforced, so that by next summer the League will have at its disposal four high-power transmitting sets, and it will be possible to receive simultaneously from twelve foreign stations. D. E. H.

Esperanto Section.

Abstracts of the Technical Articles in our last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en nia lasta Numero.

PROPAGADO DE ONDOJ.

Onda Propagado kaj la Vetero. F. Charman.

Oni priskribas preparajn provojn kunrilatigi long-distancajn signalojn (je 30 ĝis 45 metroj), kun barometra premado.

Signaloj el Nova Zelando, Aŭstralio, Brazilio, kaj Usono estis sisteme observitaj, kaj al ili oni donis fortecojn laŭ la Kodo " R." Rezultaj kurvoj montrantaj signalfortecajn variadojn kun barometraj variadoj estas donitaj kaj diskutitaj longe.

Le aŭtoro poste turnis sin al ĝenerala diskutado pri l'efektoj de la supra tavolo, montrante la efektojn de neunuforma medio kaj de konkava kaj konveksa tavolo. La ĝeneralaj meteorologaj ĉirkaŭaĵoj de la Britaj Insuloj estas poste diskutitaj, kun speciala aludo al la signalaj variadoj observitaj, dum la efekto de signalo vojaĝanta tra ciklono aŭ kontraŭciklono estas ankaŭ montrita.

Oni diras, ke la esplorado estas etendota al aliaj ondogrupoj, kaj ke oni estas ricevinta indikojn, ke la fenomenoj pritraktitaj estas ankaŭ komunaj kun la brodkasta ondogrupo.

ATMOSFERAĴOJ.

Atmosferaĵoj kaj Transatlantika Telefonio.

Raporto pri la malferma kunveno, por la 1927-1928a kunvenaro, de la Senfadena Sekcio de la Instituto de Elektraj Inĝenieroj, kun la inaŭgura parolado de la Presidento, Leŭt.-Kol. A. G. Lee, M.C., B.Sc.

La parolado traktis pri l'atmosferaĵoj aparte rilate al la Transatlantika Telefona Servado. Laboradon pri la formo de atmosferaĵoj, direkton de alveno, k.t.p., oni diskutis, kaj oni donis detalojn pri la preparaj mezuradoj, kiuj efektivigis la lokigon de la Brita riceva stacio ĉe Cupar Fifeshire.

Post diskutado pri la kvanto da elimino ebla per selektiva agordado, kaj post priskribo pri la cirkvitoj uzitaj ĉe Cupar, la parolinto turnis sin al la utiligo de direkteblaj antenaj sistemoj. Polusaj kurvoj de kelkaj malsimilaj antenaroj estas montritaj, inkluzive unu uzanta rotaciantan kadron kaj vertikalan antenon tiel kombinitan por doni polusan kurvon en la formo de mallarĝa folio.

PROPRECOJ DE CIRKVITOJ.

La Subpremo de Parazitaj Osciladoj en Valvaj Cirkvitoj. M. Reed.

La artikolo traktas ĝenerale pri la temo de Parazitaj Osciladoj. Post mallonga enkonduko, oni montras, ke estas, ĝenerale, tri eblaj oscilaj cirkvitoj, (1) Hartley'a cirkvito, (2) agorditanoda cirkvito, (3) agorditkrada cirkvito. Ĉiu el ĉi tiuj tri ekzemploj estas konsiderita detale, kaj metodoj por elimini la maldeziritan efekton estas diskutitaj. Vektoraj diagramoj estas donitaj pri la kurentoj kaj voltkvantoj necesaj en diversaj okazoj.

Tre utila resumo de la metodoj uzitaj en la artikolo estas donita en tabelo ĉe la fino, kaj du mallongaj matematikaj aldonoj estas ankaŭ donitaj.

Grafika Metodo de Amplifikatora Kupla Desegnado. Marcus G. Scroggie.

Ĉi tiu artikolo traktas pri rezisteca kapacita kuplado je aŭdeblaj frekvencoj, traktante aparte

pri la tempo-konstanto de malŝarĝo de la kupla kondensatoro. Oni ricevis esprimon montrantan la efekton de tempo-konstanto, kaj serio de grafikaĵoj ilustras la efekton de diversaj valoroj de tuta tempo-konstanto je la plimalaltaj aŭdeblaj frekvencoj.

SENDADO.

Kelkaj Eksperimentoj per Flankondara Telefonio je Mallongoj Ondolongoj. E. Howard Robinson.

Post enkonduka diskutado pri portantaj subpremaj sistemoj, kaj la utiligo sole de flankaroj, la aŭtoro ilustras " mem-rektifan " modulatoron, unue laŭ ĝia eksperimenta aranĝo kaj poste laŭ ĝia fina formo, kie ĝi evoluigas ambaŭ flankajn arojn sen portanta ondo. Oni donas longe praktikajn detalojn pri eksperimentoj pri la evoluigo de l'aparato, kun kompleta cirkvita diagramo de la sendilo kaj detaloj pri la cirkvitaj konstantoj. La ricevilo uzita en la eksperimentoj estas ankaŭ priskribita kaj ilustrita, kaj la efektoj observitaj je la funkciado de la sistemo trans longa distanco estas diskutitaj.

Aldonaĵo donas mallongan matematikan diskutadon pri la relativa utileco (laŭ la vidpunkto de ŝparado de potenco) de unuoblaj flankaraj kaj duoblaj flankaraj sendadoj.

RICEVADO.

Registrilo de Radio-Signala Intenseco. B. Saltmarsh.

Post mallonga diskuto pri la teorio de velkado kaj pri fruaj provoj kaj esploroj pri la temo, la aŭtoro pritraktis metodojn por registri.

Li poste priskribis registrilon desegnitan por elimini la disvolviĝan prokraston, kiu apartenas al fotografaj registraj metodoj. Post sufiĉa amplifado je radio-frekvenco, la signalo estas rektifita per stabila kristalo kaj la rektifita kurento pasigita tra reflektanta galvanometro. La lumo el la galvanometro trapasas optikan kojnon kaj kondensilon por aktivigi fotoelektran ĉelon, kies elmeto, post kelkaj ŝtupoj de malaltfrekvenca amplifado, aktivigas plumon funkciigitan elektromagnete, kiu skribas sur cilindro, 15 colojn (38 c.m.) ĉirkaŭe, rotacianta unufojon ĉiuhore.

Specimena registraĵo estas montrita, kun diagramoj de la optika aranĝo, k.t.p.

HELPA APARATO.

Priskribo pri Valva Ondometro kun Skalo de 10 Metroj ĝis 20,000 Metroj. F. M. Colebrook.

La ondometro estas plibonigaĵo de antaŭa desegno priskribita en *Wireless World*, 6a de Oktobro, 1926a.

Valvo, oscilanta je aŭdebla frekvenco, estas enkorpigita por apliki moduladon laŭdezire al la radio-frekvenca oscilatoro. La onda skalo estas provizita pere de serio de enŝtopaj bobenoj. La cirkvito estas modifita oscilatoro Hartley'a, kaj oni pretendas al konstanteco de normigado ĝis unu parto en milo, rilate al ŝanĝoj ĉe anodaj kaj filamentaj voltkvantoj. La baterioj bezonitaj estas enkorpigitaj en la instrumentujo.

Oni donas fotografaĵon kaj cirkvitan' diagramon montrantan la diversajn elektrajn konstantojn, kaj diskutas la ĝeneralajn detalojn de l'instrumento.

La Vibradoj de Laŭtparolilaj Diafragmoj.

Redakcia noto, citanta rezultojn obtenitajn dum eksperimentoj ĉe " Kone " Laŭtparolilo. Sablaj figuroj estas montritaj, ilustrantaj la manierojn de vibrado de la diafragmo je diversaj frekvencoj, kaj la rezultoj estas diskutitaj mallonge. Je 150 cikloj la diafragmo vibras laŭ sektoroj, kiuj plinombriĝas ĝis frekvenco de 800 cikloj, super kio la diafragmo vibras laŭ nombro da ringoj.

DIVERSAĴOJ.

Resumoj kaj Aludoj.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

Matematiko por Senfadenaj Amatoroj. F. M. Colebrook.

Daŭrigita el antaŭaj numeroj. La nuna parto traktas pri Kombinoj de Impedancoj, Grafika Prezentado de Impedancoj en Paralelo (kun diversaj valoroj de Faza Angulo), Kuplitaj Cirkvitoj (kun indukta aŭ kapacita kuplado), Amortizaj Oscilatoroj, Potenco je Alternkurentaj Cirkvitoj, k.t.p.

Procesado pri Radio-Patentoj en Usono. A. H. Morse.

Mallonga noto pri la nuna pozicio de leĝa antaŭeco en Usono rilate al patentoj traktantaj regeneradon.

LIBRO-RECENZOJ.

Recenzoj de Prof. G. W. O. Howe estas donitaj pri la jenaj germanaj verkoj :—

Transformatoraj Amplifikatoroj, de Müller kaj von Ardenne.

Poŝlibro de Senfadena Telegrafio kaj Telefonio, redakciita de Dro. F. Banneitz.

Termionaj Valvoj, de Forstmann kaj Schramm.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Amplification of Small Currents.

To the Editor, E.W. & W.E.

SIR,—I am reluctant to trespass again upon your space after the prominence you were kind enough to give my letter in your November issue. Dr. Taylor, however, after giving the sufficient reason that he was unaware of what had gone before, goes on to dismiss my method, of which he can therefore have had no experience, as less satisfactory and so unworthy of mention.

The definition given in his article of a "Thermo relay," although I disagree with the term, fits my instrument as well as it does that of Moll and Burger. It becomes a question then as to whether the latter instrument is really an advance at all. I maintain that it is not.

It cannot be held that enclosure in a vacuum is an advance over previous knowledge. This obvious refinement was embodied in several of my early designs and is mentioned in my patents, besides being well known long before that. On the remaining point of small heat capacity, thermo-couples made by my methods have frequently been exhibited, possessing much smaller mass and heat capacity than any I have seen described by Moll and Burger.

Further, the wide choice of metals available and the ease with which many junctions can be arranged in series, with suitable mounting and enclosure, provide sufficient sensibility for most purposes without the necessity of a vacuum; thus avoiding sacrifice of what the original authors term "quickness."

W. H. WILSON.

The Performance of Valves in Parallel.

To the Editor, E.W. & W.E.

SIR,—Your issue for November contains an article by Mr. R. P. G. Denman on the performance of valves in parallel.

I venture to point out that the whole treatment is based on a fallacy, and that the results obtained are, therefore, incorrect.

The fallacy lies in the assumption that the valve itself is a source of E.M.F., an assumption which is convenient and legitimate in certain cases, but which is inadmissible in the present instance.

The actual fact is that the H.T. battery or generator is the only source of E.M.F., and the valves are merely variable resistances. The fall of potential across any valve at any particular instant is exactly the same as the fall of potential across every other valve, and the flow of current in the various valves depends simply on their resistances at the instant in question.

Let $r_1, r_2, \ldots$ denote the resistances at any instant of the various valves, and let $i_1, i_2, \ldots$ denote the currents flowing through them. Let r be the combined resistance and i the total current, then

$$\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2} + \cdots \frac{1}{r_n} \text{ and } i_x/i = r/r_x$$

Taking the matter a step farther it may be assumed that $r_1, r_2, \ldots$ represent the mean resistances over a complete cycle, and that $i_1, i_2, \ldots$ are the mean currents. Subject to suitable definitions of mean resistances and mean currents the above equations would hold good when applied to mean values taken over a complete cycle.

It follows at once that the suggestion that the current in one valve can be 180 degrees out of phase with the currents in the other valves is impossible, and in fact the whole of the algebraical and numerical results in the paper are erroneous.

The correct values of the mean resistances $r_1, r_2, \ldots$ are easily determined in the case of an amplifier with a small input, for the resistances are the anode A.C. resistances of the valves. The problem in the case of an oscillator is a much more difficult one and the writer does not feel disposed to invite criticism by putting forward numerical estimates.

It is clear, however, that the variations in current between different valves working in parallel are much less than the figures given by Mr. Denman.

In large sets it is no doubt desirable that each individual valve should be operated under the conditions which will give minimum cost for a given output, but for receiving amplifiers and small transmitters the advantages to be gained by individual control would be more than counterbalanced by the disadvantages of extra complication.

K. E. EDGEWORTH.

Khartoum, Sudan.

To the Editor, E.W. & W.E.

SIR,—My article on "The Performance of Valves in Parallel" is not based on a fallacy, as announced by Col. Edgeworth in his letter.

The fact that the alternators depicted in Fig. 2 do not enjoy a physical existence in no way invalidates the assumption that the valves behave as such, in this as in other cases.

The assumption is a convenient one because it enables us to substitute for the rather awkward conception of a periodically varying resistance, the more usual idea of a fixed anode A.C. resistance to which an alternating E.M.F. is applied; but with proper treatment the two methods would inevitably lead to the same results. I say "with proper treatment" because Col. Edgeworth, having stated the equation

$$\frac{i_x}{i} = \frac{r}{r_x}$$

subsequently defines the quantities r_1, r_2 "in the case of an amplifier with small input" as the anode A.C. resistances of the valves. Having thus so far totally ignored a fundamental parameter of the triode, namely the mutual conductance, I am unable to see what "suitable definitions" Col. Edgeworth could assign to the "mean values" of the "mean currents" in his equation.

The statement that one current can be 180 degrees out of phase with the others is entirely correct, and if, after further consideration, Col. Edgeworth should require a second proof of this I can give it to him in a very simple form.

Since Col. Edgeworth has exposed no fallacy in my article, very little importance can be attached to his final statements, unsupported as they are by any kind of acceptable evidence. In my own work I came to no such positive conclusions. The present position is that the matter is being investigated experimentally by authorities on Modulation, while as regards Power Amplifiers it may be pointed out that the figures given as representing the variations of μ and r among low impedance valves were extremely conservative, for in actual practice these values cannot economically be held within closer limits than a maximum deviation of ± 25 per cent. from the nominal characteristics.

In one respect, at least, Col. Edgeworth's remarkable contribution to the subject of my article may be said to have borne good fruit, for it has led me to discover a genuine error in the work, and this I now hasten to correct.

In the discussion of Figs. 4 and 6 it was assumed that the slopes of the dynamic characteristics were constant for a given load, and would not be affected by the application of separate alternating grid voltages. But reference to the equations from which these slope conductances were derived will disclose the fact that the apparent load on each valve is partly determined by such values. The proper treatment is, as it happens, much more interesting and leads to very satisfactory results. It is briefly as follows :—

The dynamic characteristics of all parallel-connected valves should first be drawn in such a way that the excursions of grid as well as of anode potential are equal, while the algebraic sum of the current changes must be such as will give rise to the necessary change of anode potential. If now the load resistance is artificially increased until it approaches the critical value where one current reduces to zero, it will be seen that the dynamic characteristic for that valve gradually assumes a horizontal position. Subsequently its slope is reversed, showing the 180 degree phase shift already dealt with.

Now, let matters be so arranged that separate excursions are possible for the grid voltages, and we find that, merely by altering the relative values of these voltages, the slopes of the dynamic characteristics may be varied at will, the sole condition to be observed being that the product of the load resistance and the total changes of current shall be equal to the common change of anode potential.

Bearing this in mind, a brief consideration of the limiting conditions leads to a remarkably simple rule, strictly applicable only to cases where grid current is permissible, but apparently giving a sufficiently close approximation for most other purposes. This rule is as follows :—

For maximum output with a given load, the alternating grid voltages to be applied should be such as will give rise to equal current changes in all parallel-connected valves.

The adjustment is obviously one which can be effected with great simplicity, and it is particularly interesting to note that, provided the ratio μ/r is constant, any number of valves n may by this method be caused to yield the same output as a single valve of n-fold rating. Finally, since μ/r is the mutual conductance, a quantity which does remain reasonably constant in any given series of valves, I am inclined to think that the above result should prove to be of definite practical value in high-power work.

R. P. G. Denman.

Science Museum,
S.W.10.

The Theory of the Flat Projector.

To the Editor, E.W. & W.E.

Sir,—I want to clarify some points which arise from the answer which Professor Fleming gave in the November issue of *E.W. & W.E.* about my remarks on his article.

For instance, Professor Fleming finds in his article that the E.M.F. induced in the reflector wire is $\pi/2$ out of phase with the aerial current; but in his answer Professor Fleming states that this E.M.F. is in phase with the aerial current. Further, he finds in his answer that the flat projector produces, in the beam direction, with its aerials and reflector wires respectively, two fields which are $\pi/2$ out of phase, at the same place. This is in contradiction to the performance of a reflector system, which must give a wave in phase with the direct wave.

All these incompatibilities are due to the fact that the electromagnetic field's propagation, near the aerial wire, is not a simple one ; it has neither an infinite velocity in the first quarter wavelength round the oscillator, nor the velocity of light near the aerial, with a starting phase, at the oscillator, coinciding with the aerial current phase.

The propagation of the electromagnetic field near an aerial and its effect on a reflector wire was studied experimentally by W. Tatarinoff in *Zeitschrift für Hochfrequenztechnik*, October, 1926, pp. 117-120. The results are interesting. The author considers these two wires, half a wavelength in length, one being the oscillator, the other the reflector. The reflector behaves as *a pure resistance*, and its induced current lags behind the aerial current by an angle—

$$\phi=\psi+2\pi r/\lambda$$

where r is the distance between the aerial and reflector and ψ actually a function of r.

If it is supposed that the electromagnetic field, due to the aerial, has an infinite velocity in the first quarter wavelength round the aerial, and that the true radiation begins after this quarter wavelength, then—

$$\phi = \pi \quad r < \lambda/4$$

$$\phi = \frac{\pi}{2} + 2\pi\frac{r}{\lambda} \quad r > \lambda/4$$

If, on the other hand, it is supposed that near the aerial the propagation of the electromagnetic field has the velocity of light and that it starts at the oscillator in phase with the aerial current, then

$$\phi = 2\pi \frac{r}{\lambda} \quad (\psi = 0)$$

(near the oscillator).

But, actually, Tatarinoff finds experimentally that the function W of r varies in the following way:—

r	0	$\lambda/4$	$\lambda/2$	$3\lambda/4$	λ
ψ	180°	156°	135°	120°	103°
ϕ—360°	—180°	—114°	—45°	+30°	+103°

If r is increased ψ tends to $\pi/2$.

He finds, from these experimental results, the following values for r, for which the aerial and reflector fields are in phase in the beam direction:

$0.285\,\lambda \quad 0.845\,\lambda \quad 1.372\,\lambda \quad 1.875\,\lambda \quad 2.375\,\lambda$, etc. . . .

Therefore, in a flat projector which uses tuned aerial and reflector wires, the spacing between the aerials and reflectors must be $0.285\,\lambda$ and not $0.25\,\lambda$. But if the spacing is kept $0.25\,\lambda$, the same result can be obtained by detuning the reflector wires.

N.W.1. TUDOR A. TANASESCU.

To the Editor, E.W. & W.E.

SIR,—With reference to the article by Dr. Fleming on the theory of the projector, and the criticism by Mr. Tanasescu, may I be allowed to join issue in support of the latter?

1. Dr. Fleming, in the first paragraph of his reply to Mr. Tanasescu, begs the question, for there is no suggestion that the fields due to aerial and reflector of a Franklin grid do not cancel out behind the system, and add in front. What is criticised is the method of getting the result; and the chief point at issue is the definite statement by Dr. Fleming that the current in the reflector wire is in phase (or antiphase, it does not matter much which) with the current in the aerial spaced one-quarter wavelength in front.

In other words, Dr. Fleming asks us to believe that the polar diagram of two tuned aerials quarter wavelength apart, fed from a *centrally* placed transmitter (or two receiving aerials feeding a central receiver) will be a cardioid; whereas we know most definitely that the diagram will be a figure of eight. We know also that to get a cardioid from such a system we must get a misphase of currents equivalent to the spacing (90°), and one way of doing this would be to move the location of the transmitter (or receiver) to a point coincident with one aerial, which brings us back to the case of an aerial and its reflector.

Dr. Fleming will probably suggest that this is not a fair commentary, as the example above is for two driven aerials whereas the case in point is for one aerial driving another. But, however the aerials are energised, the fact still remains that for the resulting diagram to have a shadow at the back and addition in front, the phase of currents in two tuned aerials spaced quarter wavelength apart must differ by that spacing—namely, 90°, and not 180° (or 0°).

Whether in practice a half-wave aerial and a half-wave reflector driven from it will give a perfect shadow is another matter, and it may be necessary to fake the length of the reflector to bring about the desired result.

2. Dr. Fleming dismisses Mr. Tanasescu's remarks somewhat summarily by observing that he has forgotten that true radiation does not begin until quarter wavelength away. But this is most unconvincing, for if it is so for radiation from an aerial, it will be so for radiation from a reflector, and thus we are forced back to the real point at issue, the phase of currents in aerial and reflector.

3. I do not understand how a half-wave wire can be said to have a low resistance, and to be wholly inductive. Surely it has a very high resistance (radiation), and it will act as a non-inductive load to any applied E.M.F. of its natural frequency.

4. In conclusion, I would like to point out that Mr. Tanasescu makes a small mistake in stating that the spacing distance of adjacent aerials is $\lambda/4$ apart. The theoretical maximum spacing is $\gamma/2$ and, in practice, the spacing is a little less than this.

London, S.W.7. M. C. M. BHISEK.

To the Editor, E.W. & W.E.

SIR,—The article in *E.W. & W.E.* by Dr. J. A. Fleming on the Theory of the Reflector in your July issue, and subsequent letter by Mr. Tanasescu and reply by Dr. Fleming, are very interesting; but neither Mr. Tanasescu's letter nor Dr. Fleming's reply seem to clear the point completely.

Mr. Tanasescu apparently seeks to point out that as the reflector wire is considered not greater than ¼ wavelength behind the active aerial wire it is still in the direct magnetic field of the latter. Therefore the phase of the E.M.F. induced into it with respect to the current in the active aerial producing that magnetic field is 90 degrees in advance. This is analogous to the E.M.F. induced into the secondary winding of a transformer by a magnetising current in the primary.

The current in the reflector wire, if it is in resonance, will be in phase with the induced E.M.F., and will therefore be leading by 90 degrees on the current in the active aerial. The field due to the reflector wire current will therefore be leading by 90 degrees on the field due to the active aerial.

As the reflector wire is 90 degrees behind the active aerial in space, the two fields will add directly in the direction of right angles to the plane of the aerial in front of the aerial system, and will subtract directly in a direction at right angles to the plane of the aerial system behind.

If, as stated in Dr. Fleming's letter, the reflector is removed to a distance of ¾ λ instead of ¼ λ, we have an additional 360 degrees phase angle coming in, due to the additional time taken for the original wave to reach the reflector wire, *i.e.*,

$$\tfrac{3}{4}\lambda - \tfrac{1}{4}\lambda = \tfrac{1}{2} = 180 \text{ degrees},$$

and a further 180 degrees change for the reflected wave to come back.

B.B.C., London. H. L. KIRKE.

Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each

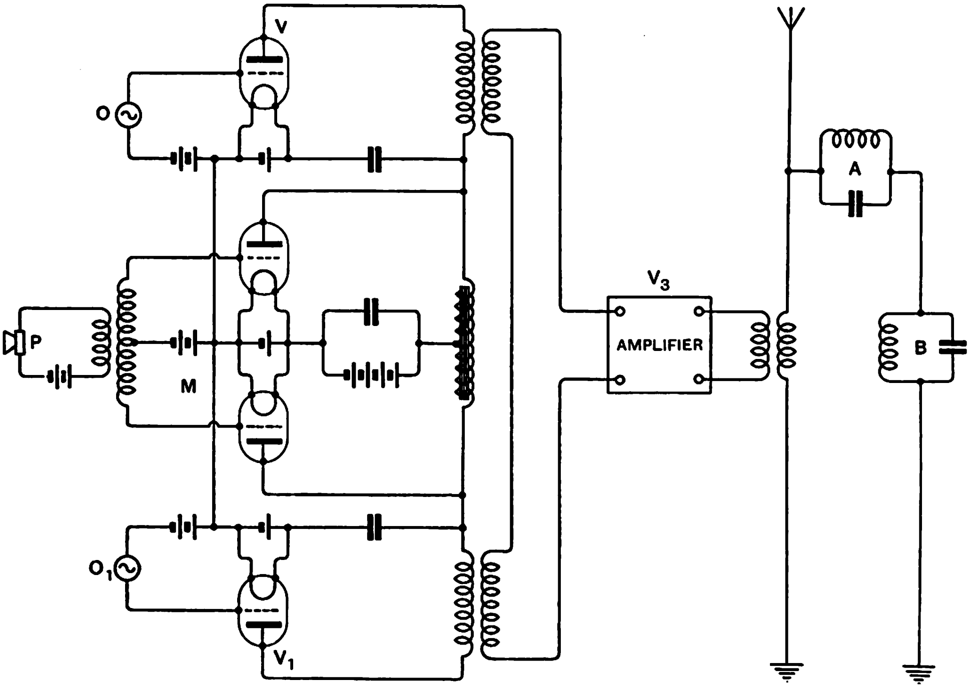
PREVENTING FADING.

(*Application date, 17th June,* 1926. *No.* 277426.)

In the case of short-wave radiation of the order of 4,500,000 cycles it has been found that a comparatively small difference in frequency amounting, say, to ten or fifteen thousand cycles, exercises a marked effect upon the incidence of fading. For instance, the periods of maximum and minimum intensity of a signal imposed upon carrier waves differing in frequency by the stated amount do not coincide. Any fluctuations which do occur appear to take place quite independently, and without having any perceptible relation to each other. It is, therefore, probable that the combined effect of two such signals at any particular station will always ensure a satisfactory degree of signal strength.

In the short-wave transmitting system shown in the figure, two independent H.F. sources O, O_1 are adjusted to have a frequency-difference of a few thousand cycles. After independent amplification in the tubes V, V_1, and simultaneous modulation by a push-pull combination M from a common microphone P, in which the signal components are impressed upon the carrier wave in phase opposition, the combined output is fed through a power amplifier V_3 to the radiating aerial. Impedance elements A, B, tuned to the two carrier waves, are inserted in the aerial so that the latter oscillates with two degrees of freedom, radiating both carrier waves equally. At the receiving end both signals are detected separately and, after passing through a phase-adjuster, are fed in parallel to the same pair of telephones.

Patent issued to Standard Telephones and Cables, Ltd.

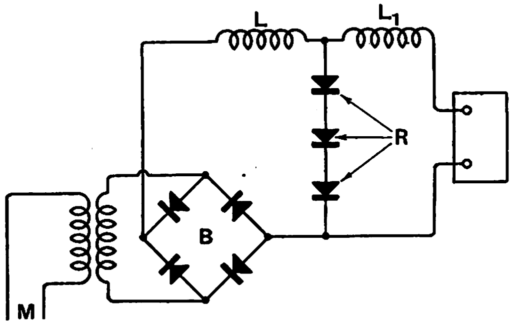


SMOOTHING CIRCUITS.

(*Convention date* (*U.S.A.*), *7th October,* 1925. *No.* 259,537.)

A full-wave rectifying bridge B, comprising four solid unidirectional elements, arranged as shown, is fed with alternating current from the mains M and passes the rectified pulsations into a smoothing circuit. The latter comprises reactances L, L_1 shunted by a bridge R consisting of galena or crystalline selenium elements, or of metallic elements similar to those used in the rectifier B.

The bridge *R* has a falling resistance characteristic, so that as the voltage applied to the inductance *L* rises, owing to the fluctuating output from the rectifier, the resistance of *R* falls. Similarly as the voltage falls the resistance of the shunt increases.



This serves to smooth-out pulsations with a minimum waste of power.

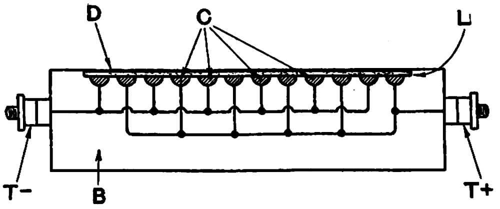
Patent issued to Westinghouse Brake and Saxby Signal Co.

MICROPHONES.

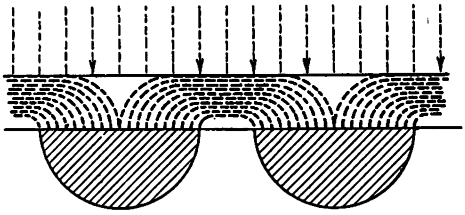
(*Application date*, 8*th July*, 1926. *No.* 278,443.)

A series of carbon-rod electrodes *C* are set flush with the surface of a wooden holder *B*, and are connected alternately to the positive and negative terminals *T*+, *T*— of the instrument. A thin layer *L* of carbon powder is sprinkled over the rods, and the whole is then closed in by a diaphragm *D*. The result is that current changes resulting from the impact of a sound-wave take place in substantially the direction of travel of the wave, as shown in Fig. B, where the dotted line arrows represent the received sound and the thicker dotted lines the current flow across the electrodes. In the ordinary type of microphone with transverse electrodes, the current variations take place at right angles to the direction of the sound-wave.

Patent issued to H. J. Round.



A

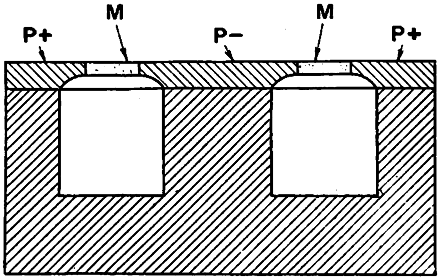


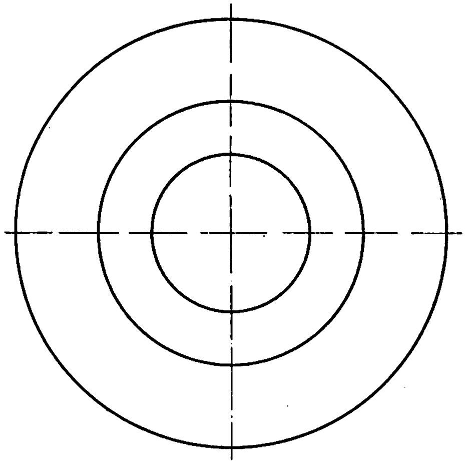
B

MICROPHONES.

(*Application date*, 23*rd July*, 1926. *No.* 278,470.)

In this instance the sensitive material consists of a conducting or non-conducting powder arranged to form a thin layer *M* or dielectric between the opposite poles *P*+ and *P*— of an electrostatic circuit. These are connected in series with a high resistance (not shown) across the terminals of a high-tension battery. Under the influence of the applied voltage, the powder will cohere in position, but thin upper and lower diaphragms of rubber may be provided to retain it in place when the battery is disconnected.





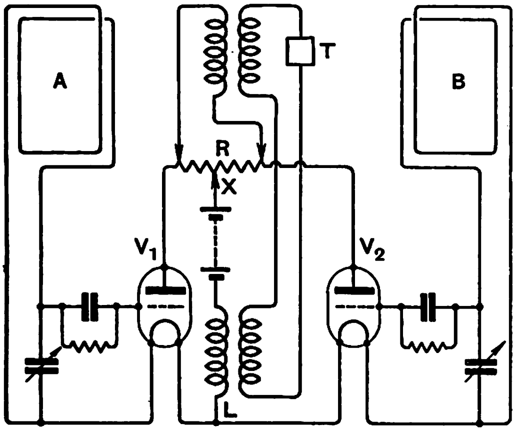
The impact of a sound-wave will cause the powder particles to vibrate in a direction at right angles to the electrostatic field, so that there is practically no constraint to their motion in this direction. The system is, therefore, highly aperiodic. Vibratory motion, due to the sound-waves, sets up capacity changes across the poles *P*+, *P*— and corresponding potential fluctuations across the series high-resistance. These may be applied directly to a suitable amplifier or may be dealt with in any suitable known manner.

Patent issued to A. G. D. West and the British Broadcasting Co.

BALANCING OUT INTERFERENCE.

(*Application date*, 13*th August*, 1926. *No.* 278,479.)

Relates to a method of eliminating interference, due either to atmospherics or undesired tuned signals, which depends upon the use of two or more different carrier-waves for transmitting the desired signal, and a corresponding number of tuned circuits at the receiving end. In the case of tuned interference, in particular, the receiving circuits can be so arranged that only one is affected by the unwanted signal. After rectification the pure-signal low-frequency component is opposed to the mixed-signal component, so that the resultant current represents the interfering signal only.



By combining the pure and mixed components additively, instead of in opposition, the resultant current will contain a double-strength pure signal component together with a component of interference. By opposing the result of the first and second operation, the final output will be a double-strength pure signal free from any trace of interference.

As shown in the figure, the two different carriers are received independently upon the aerials *A*, *B* and, after suitable amplification, the outputs from the detectors V_1, V_2 are opposed across the reactance *R*, and are added across the reactance *L*. The two effects are then combined in the desired sense in a third circuit containing the receiver *T*. By adjusting the tapping *X*, it is possible to find a point at which disturbances due to atmospherics as well as tuned interference can be eliminated.

Patent issued to J. Robinson.

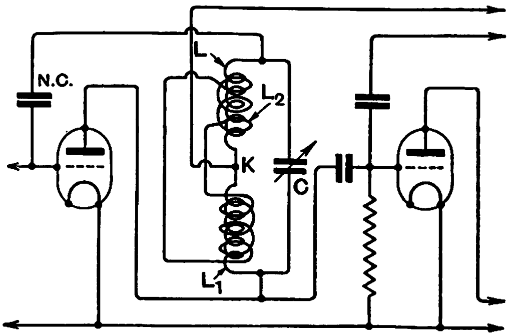
PARASITIC H.F. OSCILLATIONS.

(*Application date*, 17*th July*, 1926. *No.* 278,812.)

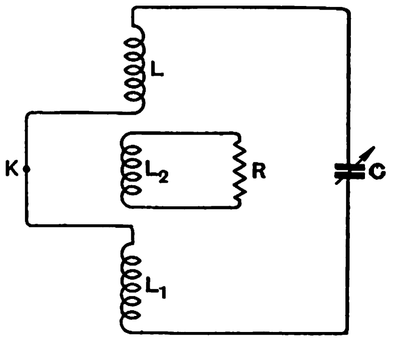
A standard method of neutralising the inter-electrode capacity of an amplifying-valve consists in connecting one end of the tuned output circuit to the anode and the other through a neutralising-condenser to the grid, the middle point of the output coil being joined to a point of steady high-frequency potential such as the H.T. battery. It is found that such an arrangement is liable to set up powerful parasitic oscillations having a frequency much higher than that of the natural tuning of the output circuit as a whole. These disturbances are due to the inherent self-resonance of the parts of the anode inductance lying on each side of the central tapping point.

It can be shown, however, that when a parasitic oscillation is built up in the half coil *L*, the main tuning condenser *C* forms a tight capacity-coupling with the other half L_1 of the same coil. The parasitic currents in the two halves of the inductance will therefore be in phase at the outer terminals of the coil. In other words the currents in *L* and L_1 will, at any given moment, be both flowing towards or away from the centre point *K*. On the other hand, the current due to the received signal frequency will flow continuously from one end to the other of the coil as a whole.

Advantage is taken of this difference in phase between the parasitic and signal currents to provide means for damping-out the former. With this object in view an additional coil L_2 is closely coupled to the main inductance, as shown either in Figs. A or B, and the direction of the windings is so chosen that the voltages induced in this winding by the signal currents are mutually opposed, so that there is no resultant current. Voltages due to the parasitic currents are, however, added together, and the resultant current is dissipated in the closed circuit formed by the coil L_2 and a series resistance *R*. The additional winding,



(A)



(B)

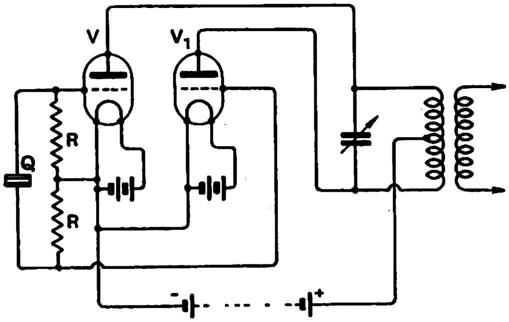
though serving to eliminate parasitic disturbances, is stated to produce no appreciable damping effect upon the desired signal.

Patent issued to N. P. Hinton, H. G. Glover, and the Metropolitan Vickers Co.

PIEZO-CONTROLLED OSCILLATORS.

(*Convention date* (*U.S.A.*), *1st September*, 1926. *No.* 277,008.)

In order to avoid disturbance in the operation of a quartz oscillator Q, due to the shunt capacity of the valve electrodes, two valves V, V_1 are arranged in series as shown with the crystal connected across the grids, in shunt with suitable impedances R. The cathode and grid capacity of both valves V and V_1 are now interposed in series across the crystal so that the total shunt capacity is reduced to less than one-half that of the ordinary single-valve arrangement.

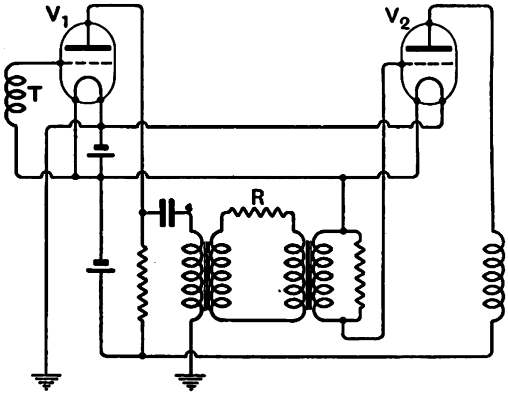


Patent issued to British Thomson Houston Co.

PREVENTING L.F. DISTORTION.

(*Convention date* (*France*), *22nd July*, 1925. *No.* 255,875.)

Relates to means for providing an automatic gain-control regulation in the low-frequency amplifiers interposed between the studio microphone and the power modulator. Such control is usually carried out by an operator or supervisor who, at best, can only remedy any defect in reproduction after it has first made its appearance. In the arrangement shown in the Figure, reliance is placed upon a resistance element R inserted in the coupling transformer between the first and second L.F. stages V_1, V_2, the former being fed from an input coil T_1 coupled to the microphone.



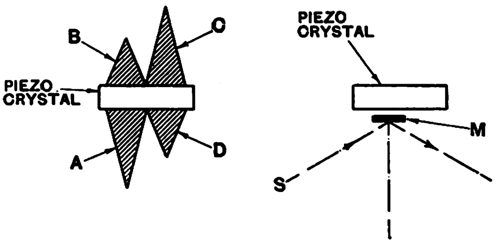
The element R is of the type in which the ohmic resistance increases with intensity of current. In actual practice the metal filament of an incandescent lamp will serve the purpose. The elasticity of the arrangement is such that the amplifying power of the whole apparatus may be ten times greater for small amplitudes than for large. Owing to the calorific inertia of the element R, the resistance-variations are not instantaneous, so that wave deformation is avoided. At the same time the regulation is far more prompt than can be ensured by any form of manual control.

Patent issued to Société Française Radio Electrique.

UTILIZING PIEZO-ELECTRIC VIBRATIONS.

(*Convention date* (*Germany*), *25th March*, 1926. *No.* 268,367.)

The invention consists broadly in a method of utilising piezo oscillations to give a visual indication of the existence and character of high-frequency currents.



(A) (B)

It has been found that when a quartz crystal is set into mechanical oscillation at its natural or inherent frequency, powerful air currents are set up at certain points along the surface of the crystal. This effect can be demonstrated by strewing a light powder, such as lycopodium, over the oscillating crystal, when it will be observed to be blown away at parts corresponding to the shaded areas A, B, C, D of Fig. A. For example, when the crystal is impulsed by a high-frequency oscillating current, the resulting air-currents can be directed against a fluid jet or siphon recorder to give a corresponding marking or indication on a moving strip of paper. Or, as shown in Fig. B, a small mirror M is pivoted close to the crystal, and is oscillated by the air-currents to deflect a light-ray coming from a source S and focused upon a sensitised film.

Patent issued to the Telefunken Co.

EXPERIMENTAL
WIRELESS
& The WIRELESS ENGINEER

VOL. V. FEBRUARY, 1928. No. 53.

Editorial.

The Design of Choke Coils and Transformers which Carry a Direct Current.

IN many of the choke coils and transformers employed in radio telegraphy and telephony, the alternating current is superimposed upon a direct current and it is now generally recognised that in these circumstances the effective inductance of the winding to the alternating current may be very much smaller than its value in the absence of the direct current. It is not so well known that the inductance in such a case can be increased by introducing an air-gap in the magnetic circuit. At first sight one would expect this to cause a decrease in the inductance, but while this is true of the inductance to an ordinary alternating current, it is not necessarily true when the alternating current is superimposed upon a direct current. If one takes a closed iron circuit which has never been magnetised since it was annealed and passes a gradually increasing current through a coil wound upon it, the relation between the magnetising force H, which is proportional to the current, and the flux density B, which is proportional to the total magnetic flux produced, will be as shown in Fig. 1. If we now decrease the current to zero, the magnetic flux does not retrace the same curve, but follows a curve like AC in Fig. 2, OC being the remanent magnetism which is very large even in soft iron if the magnetic circuit be closed. On increasing the current in the reverse direction we trace the curve CDE, where OD is the coercive force. If we now continually increase and decrease the current, first in one

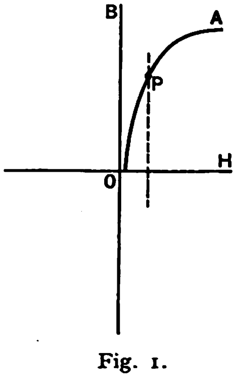


Fig. 1.

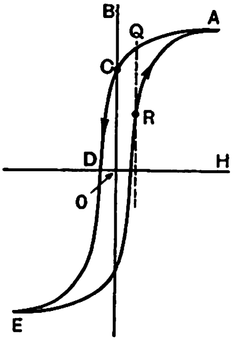


Fig. 2.

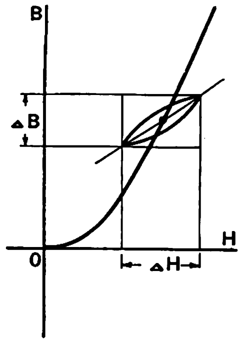


Fig. 3.

direction and then in the other, we go around the loop *ACDERA* and never again arrive at the condition shown by the curve in Fig. 1, unless we adopt special means for demagnetising the iron.

It will be seen that for a given magnetising force *H*, *i.e.*, for a given current, there are three different values of *B*, represented by the points *P* in Fig. 1 and *Q* and *R* in Fig. 2; there will be other values of *B* for loops of different amplitude.

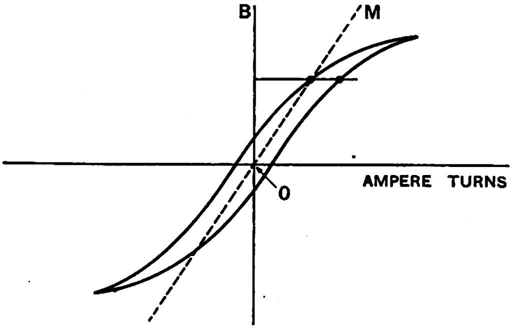


Fig. 4.

If the direct current be maintained at a value corresponding to any point on the curve and a small alternating current be superimposed upon it, it must not be imagined that one would run up and down the curves which we have just considered. The values of *B* and *H* would be found to trace out a small loop, with an axis inclined to the curve as shown in Fig. 3, so that for a given variation of the magnetising current, the variation of the flux would be smaller—in many cases considerably smaller—than one would have predicted from the curves of Figs. 1 and 2.

Consider now the effect of introducing an air-gap in the magnetic circuit. The permeability of air being always unity, the value of the ampere-turns required to drive the flux across the gap is strictly proportional to the flux density as represented in Fig. 4 by the line *OM*. For any given value of *B* the ampere-turns required for the iron part of the circuit will be unchanged, so that the total ampere-turns required are obtained by adding horizontally those for the air-gap and those for the iron. This has the effect of shearing over the loop of Fig. 1, as shown in Fig. 4. A given direct current will now produce a smaller value of *B*, and it may have the effect of bringing the centre point of the small A.C. loop down from the upper highly-saturated and flat part of the curve to an unsaturated and steep part where one may expect the small loop to be more steeply inclined. If this is so, then the effective inductance to the superposed A.C. will be increased. As the air-gap is increased, however, the line *OM* in Fig. 4 will turn further from the vertical, and the steepness of the large hysteresis loop and of the small A.C. loops will all become less and less. There will be some length of air-gap which will give a maximum value of the A.C. inductance in any given case. This optimum condition will depend to some extent on the amplitude of the superposed A.C., but one can simplify the problem by assuming that this is small compared with the steady D.C.

The ratio B/H at any point of the magnetisation curve is called the permeability at that point and is always designated by μ. In the present case, however, we are not so concerned with this ratio as with the ratio $\frac{\Delta B}{\Delta H}$ in Fig. 3. It will be noted that this is not the slope of the magnetisation curve, but the slope of the diagonal of the rectangle enclosing the A.C. loop. We shall use $\frac{\Delta B}{\Delta H}$ in this special sense and call it the incremental permeability μ_1. This subject has been studied by T. Spooner* and C. R. Hanna** and this article is based on data

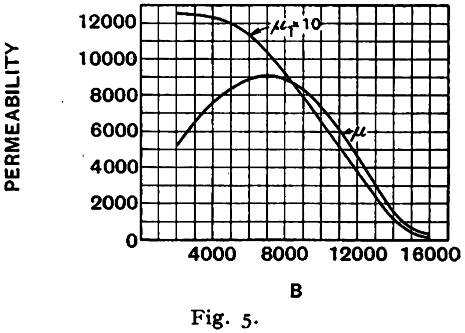


Fig. 5.

---

* T. Spooner, "Effect of a superposed alternating field on apparent magnetic permeability and hysteresis loss," *Physical Review*, 1925.

** C. R. Hanna, "Design of reactances and transformers which carry direct current," *Journal Amer. I.E.E.*, Feb. 1927.

obtained from their papers. Values of the ordinary permeability μ and the incremental permeability μ_1 for 4 per cent. silicon steel are given in Fig. 5.

In so far as the superposed alternating current is concerned we may define the self-inductance L as follows:—

$$L = \frac{\text{change of flux} \times \text{turns}}{\text{change of current}} \times 10^{-8} \text{ henries.}$$

If I = current in amperes, A = cross-section of core in sq. cms., and T = number of turns, then

$$L = \frac{AT}{10^8} \times \frac{\Delta B}{\Delta I}.$$

Now an increase of ΔB requires an increase ΔH in the magnetising force in the iron and an increase ΔB in that in the air-gap; hence if l_a = length of air-gap and l_i = length of path in the iron, $0.4\pi\,(\Delta I)\,T = \frac{\Delta B}{\mu_1} l_i + \Delta B \, . \, l_a$ = total increase in magnetomotive force.

Hence

$$L = \frac{0.4\pi A T^2}{\frac{l_i}{\mu_1} + l_a} \, . \, 10^{-8} \text{ henries.}$$

Apart from any consideration of superposed A.C., we have

$$B = \frac{0.4\pi I T}{\frac{l_i}{\mu} + l_a},$$

and substituting for T in the formula for L, we have

$$L = \frac{B^2 A}{0.4\pi I^2} \cdot \frac{\left(\frac{l_i}{\mu} + l_a\right)^2}{\left(\frac{l_i}{\mu_1} + l_a\right)} \cdot 10^{-8}.$$

Now $l_i A = V$, the volume of the iron, and therefore

$$\frac{LI^2}{V} = \frac{B^2}{0.4\pi} \cdot \frac{\left(\frac{1}{\mu} + a\right)^2}{\left(\frac{1}{\mu_1} + a\right)} \cdot 10^{-8},$$

where a is put for the ratio l_a/l_i, which we may call the gap ratio.

For the steady magnetising current I we have also

$$\frac{IT}{l_i} = \frac{B}{0.4\pi}\left(\frac{1}{\mu} + a\right).$$

These two formulæ are employed by Hanna to develop a very simple graphical method of design. For an assumed value of the gap ratio a, several values of B are taken and from the corresponding values of μ and μ_1 (see Fig. 5), the values of LI^2/V and IT/l_i are calculated, and the former plotted against the latter as shown in Fig. 6, which shows a number of curves obtained for different assumed values of a. A curve is drawn just touching all these curves, and it can be seen that this envelope curve gives the relation between LI^2/V and IT/l_i, if the best value of a is always chosen. It will be noticed that the ordinate LI^2/V is a quantity which, if divided by the square of the current, gives the inductance per cubic centimetre of the iron employed. The value of a to be employed at any point of the envelope curve is the value corresponding to the individual curve which is tangential at that point. In Fig. 7 the envelope curve is drawn and divided to indicate the values of a corresponding to different points on the curve. This curve is the working curve in the design. Suppose

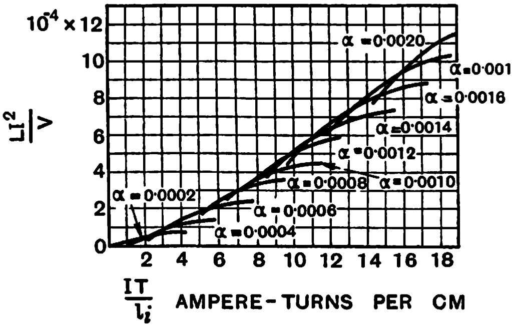


Fig. 6.

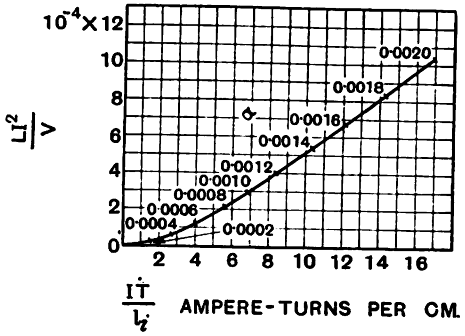


Fig. 7.

that it is required to design a suitable winding and air-gap for an iron core of given dimensions, the continuous current I and the A.C. inductance L being given, LI^2/V can be calculated and the values of IT/l_i and α read off the curve in Fig. 7. This fixes the air-gap and the number of turns. If it is found impossible to get the requisite turns into the available space without an excessive resistance, then a larger iron core must be taken and the process repeated. The largest obtainable inductance from a given core is thus seen to be limited by the allowable resistance, the air-gap being always adjusted to the optimum value for the inductance.

It will be seen that the value of α lies between 0.2 and 2 parts in 1,000.

In the original paper, curves are also given for hypernik, a 50 per cent. nickel iron, and experimental results given showing a close agreement with calculation.

Before utilising the method it is necessary to determine the curve of incremental permeability μ_1 for the iron to be employed; little has been published on this subject. Apart from utilising the methods outlined in the design of new inductances it is obviously advisable to test any already in use with a view to determining whether their performance might not be improved by the introduction of an air-gap in their magnetic circuit. This only applies to those cases, and they are many, where the windings carry a direct current.

G. W. O. H.

Rectification as a Criterion of Distortion in Amplifiers.

By Manfred von Ardenne.

If the pointer of a milliammeter connected in the plate circuit of an amplifying valve moves during reception, a rectifying effect is present which has a definite relation to the distortion. This method of stating the distortion by the detection effect and determining, in this way, the distortion factor, is very advantageous, as the measurements can be carried through comparatively easily and, moreover, the influence of the plate-circuit resistance on the curvature of the working characteristic is considered automatically. If the grid-currents remain smaller than 10^{-8} ampere, *i.e.*, in thoroughly evacuated valves, and the grid-voltages never get less negative than -1 volt, then the valve-distortion depends only upon the curvature of the static characteristic and on the valve and the kind of the resistance in the output circuit. When an alternating sinusoidal potential is impressed on the grid and the working characteristic is curved in the corresponding range, an alternating current is produced in the plate-circuit which contains not only the fundamental frequency but a number of harmonics, thus causing disagreeable distortion. The amplitude of the various harmonics could be deduced from the curvature of the working characteristic and the value of the alternating grid potential, but as the required physiological and acoustic researches had not yet been carried out, it would be useless at the present time to work out the amplitudes of the various harmonics, the more so as they will depend on the actual shape of the curvature. The production of harmonics due to the bend of the curve usually results in a change δI_a. Only when the working point is exactly on the inflection point of the characteristic is it likely that harmonics will be produced without noticeable rectification. This will happen occasionally in power amplifiers. In general practice, however, the distortion due to the lower bend is of far greater importance. So long, therefore, as the working characteristic is utilised only where the curvature is in one direction, it is possible to estimate the distortion from the detection effect. To get a measure for the distortion or, what amounts to the same thing—for the sensitivity of the rectifying effect—one may compare the variation δE_g

of steady grid potential which would cause the same variation δI_a of anode current with the amplitude E_g of the alternating grid potential which actually causes it. Thus

$$\delta E_g = \frac{\delta I_a}{S_r} \quad \ldots \quad \ldots \quad (1)$$

$$\text{and } K_v = \frac{\delta E_g}{e_g} \quad \ldots \quad \ldots \quad (2)$$

is a measure of the rectifying effect.

In the equation (1) S_r means the steepness of the static "working" characteristic in the respective point, *i.e.*, of the valve together with the anode resistance. This steepness S_r is related to that S of the valve itself by the formula $S_r = S\,\dfrac{R_i}{R_a + R_i}$. The current increment δI_a of a valve with any plate circuit arrangement of impedance Z will amount to

$$\delta I_a = \frac{\partial S}{\partial E_g} \cdot \frac{R_i^2}{|Z+R_i|^2} \cdot \frac{e_g^2}{4} \cdot \frac{R_i}{R_a+R_i} \quad \ldots \quad (3)$$

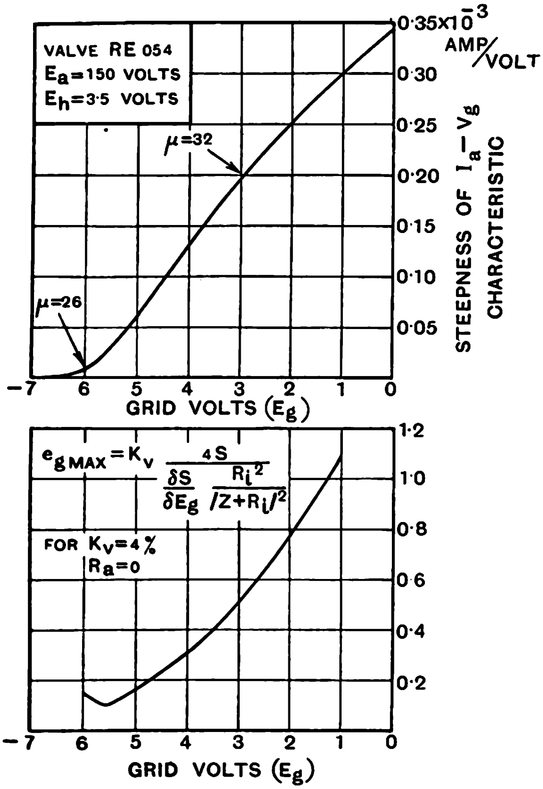


Fig. 1.

$|Z+R_i|$ means the absolute value of the joint impedance of the valve and anode circuit.

In the above equation $\partial S/\partial E_g$ represents the curvature of the static valve-characteristic. The factor

$$\frac{\partial S}{\partial E_g} \cdot \frac{R_i^2}{|Z+R_i|^2}$$

may be regarded as the curvature of the dynamic characteristic. It is obvious, that the effective curvature of the dynamic working characteristic decreases rapidly as the value of the plate circuit resistance exceeds that of the valve itself (R_i). From equations (1) and (3) the following relation is obtained for the distortion factor

$$K_v = \frac{\dfrac{\partial S}{\partial E_g} \cdot \dfrac{R_i^2}{|Z+R_i|^2}}{4 . S} . e_g \quad \ldots \quad (4)$$

This equation shows that the potentials to be applied to the grid, without exceeding the critical distortion factor, are inversely proportional to the curvature of the dynamic

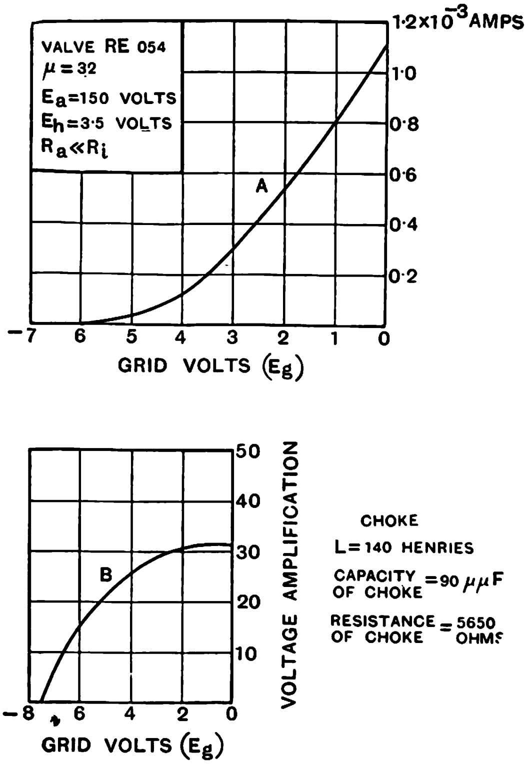


Fig. 2.

working characteristic. Experiments carried out with a Western Electric loud-speaker and with the aid of trained musicians showed that in transmitting orchestral music a distortion factor in the power stage of less than about 4 to 6 per cent., and in the last stage but one less than 4 per cent., is necessary.

It is often interesting to ascertain how large the grid-potential input may be without exceeding the critical distortion factor for a given working point on the characteristic. The maximum value of the grid potential input is seen from formula (4) to be

$$e_{g\ max.} = K_v \frac{4.S}{\frac{\partial S}{\partial E_g} \cdot \frac{R_i^2}{|Z+R_i|^2}} \qquad (5)$$

If the maximum grid-potential input is calculated for static conditions and special care is taken that it does not exceed the value derived from equation (5), the distortion factor can never exceed the critical value, because the *dynamic working characteristic* is always less curved than the static valve characteristic, assuming the same working point in each case. For an ordinary valve used in a resistance coupled amplifier the maximum grid potential input has been ascertained for a distortion factor of 4 per cent. and various grid voltages (see Fig. 1).

Using a plate potential of 150 volts and a grid bias of 3 volts, the grid potential input should not exceed 0.5 volt lest the distortion factor should exceed 4 per cent. It will be seen from the curves that this valve gives a mean amplification of 30. To the given grid potential input there corresponds an alternating plate potential of 15 volts amplitude, which is about all that can be utilised in the power stage without exceeding the distortion factor of 4 to 6 per cent. It need not be pointed out that in using amplifiers with the same distortion factor one should prefer, of course, always that one which gives the largest voltage amplification, since it applies a larger output potential to the grid of the next valve. The distortion factor might be expressed by the formula

$$K_v = \frac{\partial E_a}{e_a} \qquad \dots \qquad \dots \qquad (6)$$

assuming the alternating plate potential to be fixed at that value which just starts to overload the following valve.

It has been mentioned above that when a resistance is connected in the plate-circuit the distortion will always be smaller than

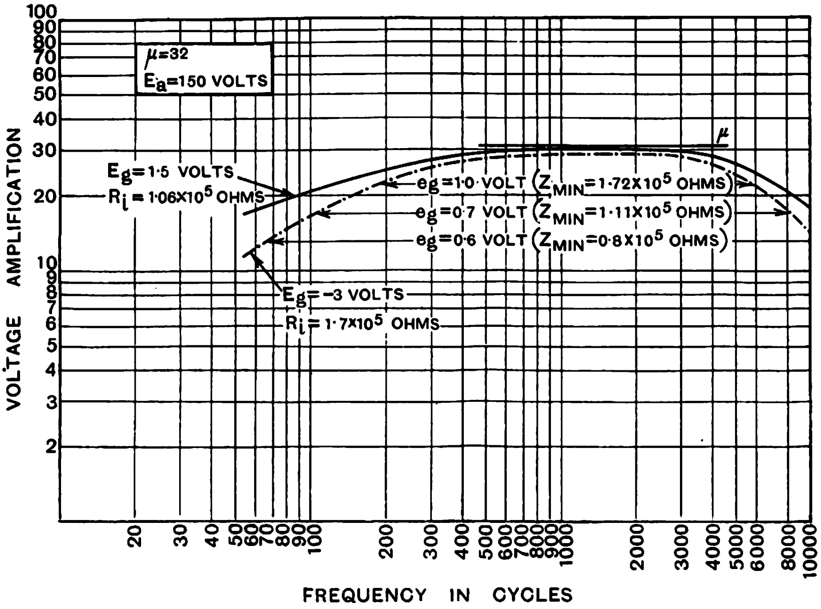


Fig. 3.

expected from the static valve characteristic. In choke-coupled amplifiers the valve impedance at the ordinary grid bias and plate potential is given and not the value of the plate-circuit impedance Z, which is dependent on the frequency. In this connection it is interesting to calculate how large the minimum value of the plate-circuit reactance has to be, in order to amplify under given circumstances a certain grid potential input with the critical distortion factor. This minimum value of $|Z|$ follows from a simple transforming of equation (4)

$$|Z| = R_i \left\{ \sqrt{\frac{\partial S}{\partial E_g} \cdot \frac{D . R_i . e_g}{4 . K_v} - 1} \right\} \qquad (7)^*$$

As a practical example, Fig. 3 shows the results for a choke-coupled amplifier with data according to Figs. 1 and 2. The critical minimum value of $|Z|$ has been calculated for various grid potentials and a distortion factor of 4 per cent. This amplifier is fairly independent of all grid potential variations up to 0.6 volt within the range of the respective frequencies. A grid-potential input of 0.7 volt, for example, will be amplified only within the range of 110-8,500 cycles sufficiently free of amplitude distortions. The dimensions and constants of this amplifier, which is, by the way, suitable for many purposes, are given in Figs. 1, 2, A, B, and 3.

It is worth while to draw attention in this connection to the high inductance value of the choke. To explain the exceptionally large value it should be added that the plate current of the valve employed, which had a large amplification factor, was very low and the choke coil itself was only weakly pre-magnetised in spite of the high number of windings. Obviously, the same conditions are given in transformer-coupled amplifiers using valves with high voltage amplification factor. To get a clear conception of the distortion it is better to express the distortion factor by the ratio of currents than by that of voltages. Thus the detection effect can be expressed in terms of the amplitude I_a of the alternating plate current, which should correspond either to the grid-potential input or the alternating plate potential, by the following relation

$$K_v = \frac{\delta I_a}{I_a} \qquad \ldots \qquad \ldots \qquad (8)$$

This formula is specially useful in the case of power stages. The amplitude of the plate current might at the utmost become equal to the ordinary current I_a which flows when the transmission is interrupted. From this definition of the distortion-factor one obtains the following value for the maximum fluctuation of the plate current.

$$I_a = K_v . I_o \qquad \ldots \qquad \ldots \qquad (9)$$

From this equation, for example, it can be inferred that the fluctuation of a sufficiently inertialess ammeter in the plate circuit of a power valve should be lower than 0.05 of the indicated value, in order to obtain good reception on a good loud-speaker of the diaphragm type.

On account of the large amplification usually obtained in modern low-frequency amplifiers the amplitude of the grid potential in the first stages is usually smaller than 0.05 volt. For this reason there is in the first stages no perceptible amplitude distortion (due to curvature of the working characteristic), the principal problem here being only to bring about as high an amplification as possible in the required range of frequencies.

---

* It should be noted that with choke coupling $|Z+R_i|^2 = Z^2 + R_i^2$. It should also be noted that $D = 1/\mu$ and therefore $DSR_i = 1$.

Further Notes on the Reflex Voltmeter.

By W. B. Medlam, B.Sc., A.M.I.E.E., and U. A. Oschwald, B.A.

Description.

THE reflex type of voltmeter was suggested by the authors* to overcome the disadvantages of the ordinary types that they have a very restricted range, and that their scales are far from being linear. The scale of a reflex voltmeter may be made linear within about 2 or 3 per cent. over 80 per cent. of its range, and any range may be obtained, with a moderate H.T. voltage, up to about 50 volts R.M.S. without the use of any grid bias cells. The essential connections of the voltmeter are shown in Fig. 1. It will be seen that a high resistance, *R,* is connected between the negative ends of the H.T. and L.T. supplies. The action of this high resistance is two-fold. As it is connected in the plate circuit, and carries the plate current, there will be a voltage drop across it. Thus the plate potential is reduced as the current is increased. The effect of this is to make the scale of the indicating instrument in the plate circuit less open at the higher readings, and hence more linear. As the resistance is also connected in the grid circuit the P.D. across it, due to the anode current through it, acts as a negative grid bias. Thus the resistance provides automatically a negative grid bias proportional to the input voltage on the grid. The first effect of this action is to increase very greatly the amplitude of A.C. voltages which may be applied to the grid before grid current occurs. It may be noted that this increased range is obtained without sacrifice of sensitivity with low inputs as the bias falls with the input. The second effect of the action of the resistance in the grid circuit is to slow down still further the rate of increase in plate current with increased A.C. input to the grid, leading to a further improvement in the linearity of the scale of the instrument.

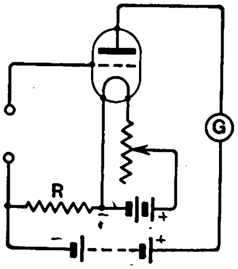


Fig. 1. *Essential connections of reflex voltmeter.*

Effect of Capacity across the Resistance.

The presence or absence of capacity across *R* will make a great difference to the calibration of the voltmeter.* If there is no capacity the plate current through *R* will be pulsating at the frequency of the input voltage, and the grid bias due to the P.D. across *R* will vary in unison with the outline of the input voltage. If *R* is shunted by a large capacity the P.D. across it will be practically steady, and the grid bias will vary little—if at all—throughout the cycle.

If the voltmeter is used without any shunt capacity other than the self-capacity of the resistance a linear calibration appears to be obtainable rather more easily, but the calibration will vary with the frequency, and there will be a loading effect on the input circuit due to the resistance.

If a shunt capacity is used of such a value that its reactance at any frequency on which the voltmeter is to be used is small compared with the ohmic resistance *R*, then the calibration of the voltmeter will be independent of frequency. For example, with resistances down to 100,000 ohms, a capacity of 2μF would be safe at any frequency down to 50 cycles. The capacity, in addition, cuts out entirely the loading effect of *R* on the input.

From the above it appears preferable to calibrate and use the voltmeter with the resistance shunted by a condenser.

**E.W. & W.E.*, November, 1926.

* See also *Note sur le Voltmètre Thermoionique*, by M. Jean Marique, in *Q.T.C.*, Nos. 2 and 3.

Provision of Bias.

The negative grid bias necessary for the voltmeter may be provided partly by cells and partly by the P.D. on the resistance, or it may be provided entirely by the resistance. The disadvantage of the latter method is that the instrument deflection with no input voltage will probably be large, and it will be necessary either to "set up" the pointer, or to balance out this initial current electrically. A small initial bias helps to reduce this current, but if this bias is large the lower part of the scale is adversely affected. The authors' personal preference is to use the voltmeter without any grid cells at all.

Values of Resistance and H.T.

For any given resistance there will be a least value of H.T. which can be used. This value depends on the type of valve and on the range of the voltmeter. For example, suppose a voltmeter is required to read up to 25 R.M.S. volts. Assuming a sine wave, the peak input will be 35.3 volts, and the negative bias with full input should be not less than about 36 volts. If the resistance is 100,000 ohms, and this has to supply the whole of the bias, the anode current must not be less than $36 \times 10^6/10^5$ $=360$ microamps with the maximum input. It is necessary to raise the H.T. until this current is obtained.

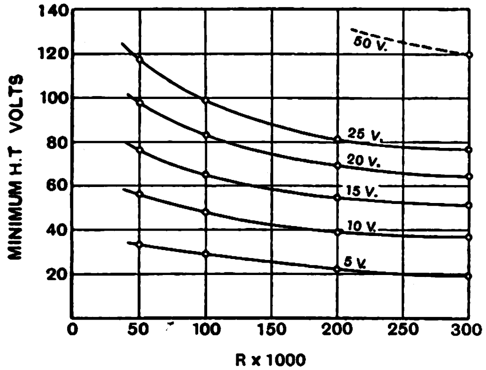


Fig. 2. *Variation of minimum H.T. with reflex resistance for various voltmeter ranges, with DE5 valve.*

The relation between this minimum H.T. and the value of *R* is shown in Figs. 2 and 3 for two different types of valve, and for the voltmeter ranges (R.M.S. volts for full scale reading) shown on the curves. It will be seen that for a given range and given resistance, the H.T. required for the DE5 valve—owing to its greater emission—is much less, in all cases, than for the R-type valve. If the H.T. is limited to 120 volts a voltmeter range of 50 volts is practicable for the DE5, against only 25 volts for the bright valve. Secondly, for any given range, the H.T. becomes less as the resistance is increased, but while there is little to be gained in this respect by increasing the resistance above 200,000 ohms for the DE5, the value for the R valve may exceed 300,000 ohms, and thus pull down the H.T. by another 10 volts or so.

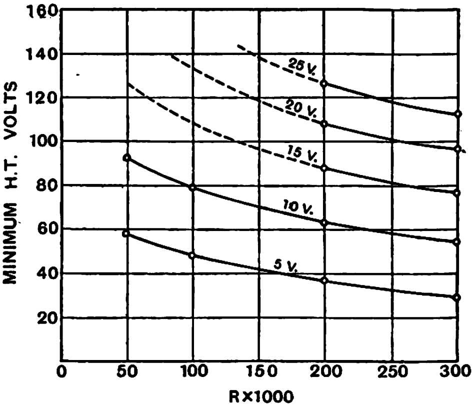


Fig. 3. *Variation of minimum H.T. with reflex resistance for various voltmeter ranges with R-type valve.*

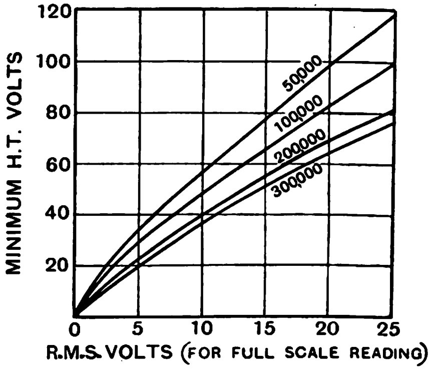


Fig. 4. *Variation of minimum H.T. with voltmeter range for various reflex resistances, with DE5 valve.*

The working conditions for intermediate ranges may be determined from the curves in Figs. 4 and 5, which have been deduced from Figs. 2 and 3.

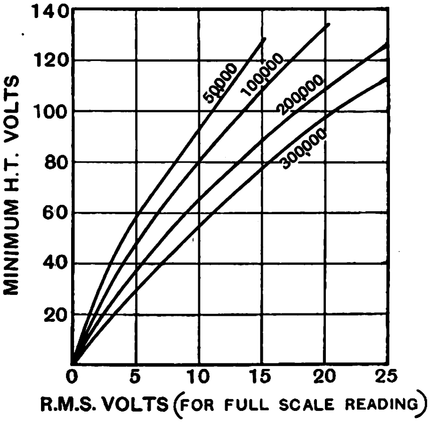


Fig. 5. *Variation of minimum H.T. with voltmeter range for various reflex resistances, with R-type valve.*

Calibrations.

Specimen calibration curves are given in Figs. 6 and 7 for a DE5 valve, for various voltmeter ranges and resistance values. The curves in Fig. 6 all refer to a 10-volt range, with the values of resistance and H.T. given in Table I.

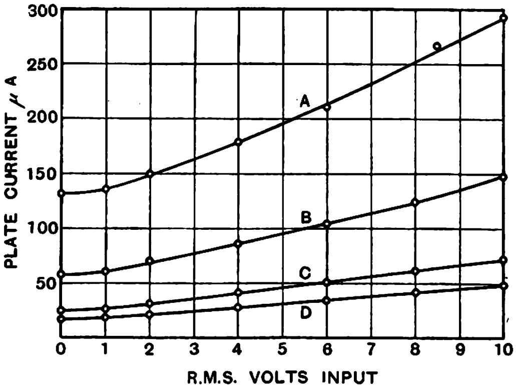


Fig. 6. *Calibrations for 10-volt range, with DE5 valve.*

The curvature of all these calibrations is very small from 2 volts upwards.

In Fig. 7, curve E is a calibration for a 25-volt range with $R = 100{,}000$ ohms, and H.T.=100 volts, while curve F refers to the same range with R=300,000 ohms, and H.T.=80 volts. Curve G is a calibration for a 50-volt range, with R= 300,000 ohms and H.T.=120 volts. These calibrations may be considered linear over 80 per cent. of the scale.

In all the above calibrations the whole of the grid bias is provided automatically by the P.D. on the resistance, and the grid bias conditions are safe at every point for the peak of the input voltage, assuming a sine wave. The H.T. used is, in each case, the nearest convenient value above the minimum obtained from Fig. 2 (or Fig. 4).

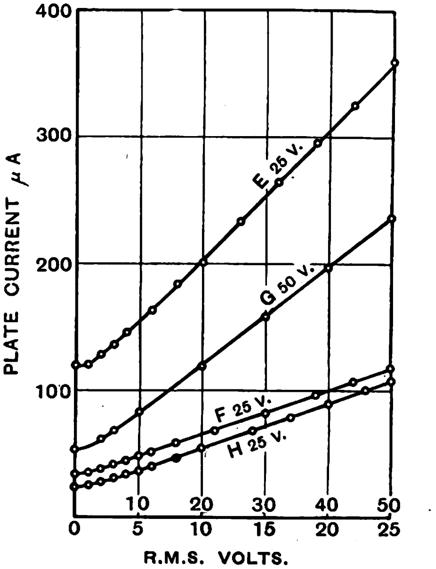


Fig. 7. *Calibrations for 25- and 50-volt ranges, with DE5 valve.*

Graphical methods of calculating the calibrations of reflex voltmeters have been developed by M. Jean Marique in a Belgian wireless review.*

TABLE I.

Curve	A	B	C	D
Resistance	50,000	100,000	200,000	300,000
H.T.	60	50	40	40

---

* *Loc. cit.*

Initial Current Balance.

It will be noted from the calibrations given above that the initial deflection with zero input is such an appreciable proportion of the full scale deflections that it is advisable to adopt means to reduce or to eliminate its effect. One method is to apply a small initial bias by means of cells. The effect of this is illustrated in Fig. 7, in which curve *H* is a calibration taken with the same resistance and H.T. as for curve *F* but with an initial bias of —4 volts. The calibrations are practically parallel throughout: the initial bias produces the same reduction in full scale current as in the current with no input, but the ratio of these currents is, of course, greater for the lower curve. The useful length of scale depends on this ratio, and is somewhat greater when initial bias is used. A mechanical method of eliminating the initial current is to "set up" the pointer, by means of the zero adjustment, until it comes to the zero of the scale when the filament emission is correct with zero input. This method must be used with care as, with too large a set up, the pointer may be bent when the instrument is suddenly switched off from full scale reading. Another disadvantage of this method is given below.

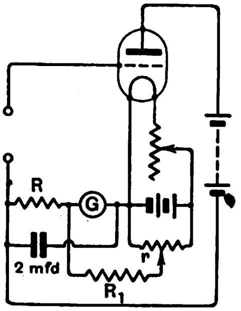


Fig. 8. *Reflex voltmeter with initial current balance.*

The usual electrical method is illustrated in Fig. 8, in which *r* represents a potential divider connected across the filament battery, and R_1 a high resistance to minimise the shunting effect of *r* across the galvanometer. The potential divider may be of 300-ohm resistance, and R_1 may have a value between, say, 10,000 and 50,000 ohms for galvanometer resistances up to 1,000 ohms.

If R_1 is too low the shunting effect of it in series with a portion of the potential divider may vary appreciably with the position of the slider. The resistance in the circuit due to the potential divider may vary from zero, with the slider at either end to a maximum value of 75 ohms with the slider in its mid position on a 300-ohm resistance. If R_1 is too high insufficient current may be obtained in the local circuit to balance out the plate current. In practice it is preferable to make R_1 nearer its upper rather than its lower limit as this gives finer control on *r* of the balance current.

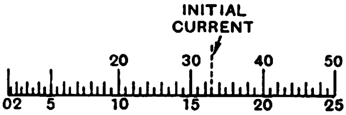


Fig. 9. *Scale of reflex voltmeter for 25- and 50-volt ranges.*

Two Range Voltmeter.

As, in this reflex voltmeter, the plate current with maximum input voltage is determined by the value of *R* and the minimum P.D. it is necessary to develop across it according to the input voltage, it will be necessary, in general, to shunt the galvanometer to bring the reading with this current to the top of the scale. It is convenient to add an additional shunt which will increase the current through the instrument so that full scale reading is obtained with half the maximum input—thus giving a second voltage range of half the maximum range. As the calibrations are so nearly linear the same scale may be used for both ranges with little sacrifice of accuracy.

Consider, for example, the 50-volt calibration shown by curve *G* in Fig. 7. We may arrange a shunt such that with 25 volts input the required current of 139μA —or better, the increase of 85μA from the "zero" of 54μA when the initial current is balanced—gives full scale reading. The scale may then be equally divided from 25 volts at the top down to 10 volts, the divisions below 10 volts becoming smaller. To read inputs between 25 and 50 volts, the shunt may be tapped to reduce the current through the instrument until its reading with 50 volts input is the same as for 25 volts on the lower range. The multiplying factor of 2 will then hold fairly correctly down to the 10-volt division. This scale is shown in Fig. 9.

The initial current "zero" (54μA in this case) must be marked on the scale to enable the correct filament emission to be obtained when the voltmeter is first put into operation.

It may be pointed out that with the electrical method of balancing the initial current (Fig. 8) the balance is unaffected by shunting the galvanometer, or by changing the shunt, so that no readjustment is necessary when changing the range of the voltmeter; but with the mechanical method the set up must be altered each time the range is changed.

Operation of Voltmeter.

The method of putting the voltmeter into service is as follows: See that the current balance is switched off, that the *low* range shunt is in action if the voltmeter is of the two range type, that the H.T. is of correct value, and that there is a closed grid to filament circuit. Then switch on the filament and increase the plate current until the pointer comes to the initial current line on the scale. Leave the voltmeter for five minutes or so, then readjust the filament current if any change has occurred. Continue readjustments until constant conditions are obtained then switch on the balancer and adjust until the pointer is moved back to the true zero of the scale. The voltmeter is then ready for service.

Voltmeter with Broken Input Circuit.

The connections may be arranged so that the voltmeter is unaffected by D.C. voltages across its input by inserting a grid condenser and leak as shown in Fig. 10. This diagram shows the complete connections with a current balance and tapped shunt for two ranges.

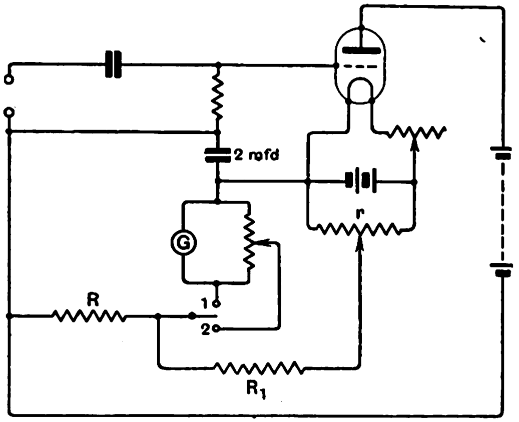


Fig. 10. *Two-range reflex voltmeter with current balance and grid condenser and leak.*

Tetrode Voltmeter.

Further applications of the reflex principle to four-electrode valves have been suggested and some experimental results given, in *Q.T.C.**

---

* *Loc. cit.*

A New Method of Using Resistance Amplification with Screened Grid Valves.

By John J. Dowling, M.A., F.Inst.P.

IN view of their high impedance "screened grid" valves have not hitherto been employed to any great extent except in tuned high-frequency circuits. It is the purpose of this note to describe a method whereby these valves may be used to obtain really enormous amplifications in aperiodic circuits of the resistance coupled type.

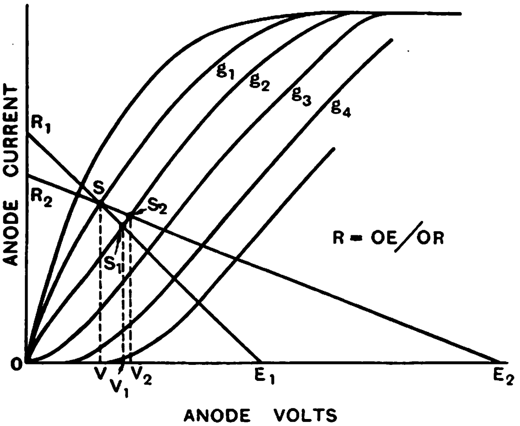


Fig. 1.

Consider in the first place the well-known graphic representation of amplification in a triode resistance amplifier stage. In Fig. 1, the curves g represent the different anode current-voltage curves corresponding to equal steps (u) of grid voltage. If E_1 is the voltage of the H.T. battery and E_1R_1 is drawn so that $E_1O/OR_1 = R_1$, the series resistance to be used, this line cuts the curves in such points as SS_1. For a grid voltage g_1 the actual anode voltage is OV. If the grid voltage is made more negative (g_2), the intersection S moves to S_1 and the anode voltage *rises* to OV_1. Thus the voltage amplification is

$$\frac{VV_1}{g_1 - g_2} = \frac{VV_1}{u}.$$

Let a higher resistance R_2 be used; a higher battery voltage will be required in order that the line E_2R_2 may still cut across the curves where they are straight and equi-spaced (this is desirable to avoid distortion). The amplification ratio will now be

$$\frac{V - V_2}{u},$$

which is greater than before.

The maximum (theoretical) limit is attained when ER is horizontal: a condition corresponding to an *infinite* resistance R, which is naturally impossible of actual attainment.

Fig. 2 illustrates, roughly, the contours of the same curves for a screened plate valve. An actual test will show that the amplification ratios for either of the possible "resistance lines" ES and ET are much less than would be obtained with an appropriate *triode resistance* combination working with the same H.T. voltage.

Consider now the part of the curves, between XY, *where they slope downwards*. In Fig. 3 these portions are drawn for two curves corresponding to a very small difference in grid voltage (say 2/100 volt). The "resistance line" ER here cuts very obliquely across the curves, although its actual slope is quite steep and corresponds

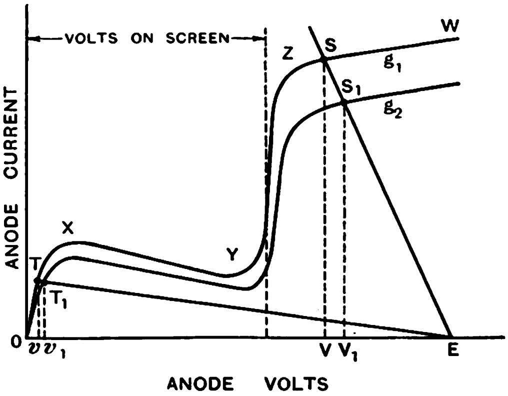


Fig. 2.

to a resistance R of moderate value. For the small change in grid voltage from g to g_1 a very great alteration occurs in the anode voltage $(V_1 - V)$. We thus have a condition capable of yielding enormous amplification.*

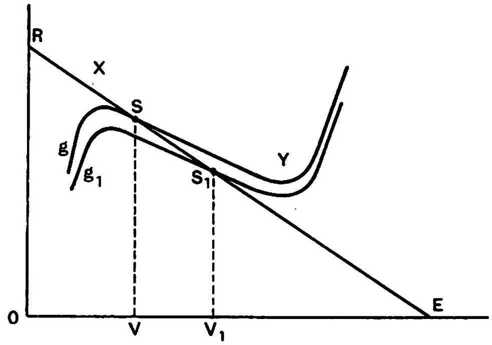


Fig. 3.

It is unfortunate that the range of anode voltage change available for the process lies between XY, which is in practice about 30 volts. This restricts the application of this method to the magnification of minute voltage fluctuations of the order of hundredths of a volt. Nevertheless it should prove of value in certain cases. Probably valves of the dynatron type could be designed to give a more extended range.

To satisfy myself that the above process could be carried out and that the hoped for results could be attained without instability in the apparatus, an experiment on the lines of Fig. 4 was performed. The valve was a Marconi S625, the screen grid voltage 80 and the H.T. 120 volts. R was made 180,000 ohms, which was the value estimated to produce the greatest possible stable amplification when E is 120 volts and *the grid voltage adjusted* so that the line ER intersected the curves as shown in Fig. 3. This grid voltage adjustment was made by a potential divider giving steps each of .02 volt. The electrostatic voltmeter was an Ayrton Mather instrument with an 80-volt battery (not shown) in series to bring the deflection to the most sensitive part of the scale. The measured amplification was almost exactly what was expected from the values of the R and E chosen, and the contours of the curves as previously plotted, namely, 150 *fold.* With greater values of the resistance the setting becomes unstable, but with smaller ones a lower amplification is obtainable if the H.T. voltage E be reduced or the mean grid voltage raised to suit.

As will be readily apparent on consideration of the contour of the curves (Figs. 2 and 3), provided that the resistance R chosen is not too large (nor the value of E) the only adjustment required in practice is to vary the grid potential by a potentiometer until the valve is operating at such a grid voltage that the characteristic curves are intersected by the "resistance line" ER within the region XY. The method is thus quite simple to carry into practice.

I may point out in conclusion one drawback. Usually the parts XY of the various curves are not exactly parallel. This may cause unequal amplification for weak and strong signals. The effect of this in audio-frequency amplifiers may be unpleasing to the ear for telephony, but it is of little importance in telegraphic work.

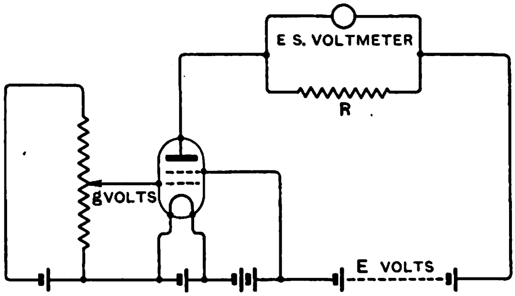


Fig. 4.

---

* Unlike the ordinary case of resistance amplification there is no *theoretical* limit to the amplification ratio obtainable, since the process does not depend on a valve amplification factor.

The Accuracy and Calibration Permanence of Variable Air Condensers for Precision Wavemeters.

By W. H. F. Griffiths, A.M.I.E.E., Mem.I.R.E.

(Concluded from page 24 of January issue.)

A Serious Defect.

In this simple construction an important defect has, for simplicity, been ignored. It will be seen that a relatively large capacity will be present between the portions of the surfaces of adjacent moving plates *IP* which are not interleaved—a capacity which will become larger as the actual capacity of the complete condenser is reduced. This inter-moving plate capacity militates against the scheme of "constancy of capacity irrespective of the lateral positions of the moving plates" as the diagram (Fig. 9) of the resultant electrical system of three fixed plates and two moving plates will show. Fig. 10 is a simplification of this diagram and by an inspection of this it will be seen that whilst the moving plates *MP* are revolving truly and exactly midway between the adjacent fixed plates the series capacities C_5 and C_6 are equal and C_7 and C_8 are equal, the two moving plates MP_1 and MP_2 being, therefore, equipotential conductors. Under these conditions the interplate capacity C_9, whatever its value, does not contribute to the resultant capacity of the complete condenser system. If, however, the two moving plates, for some reason, fall slightly the capacities C_6 and C_8 are increased, and although the resultant capacity of the condenser system will not be affected by this movement if the capacity C_9 is zero the constancy will be impaired in practice as this latter capacity is of a very appreciable order. Even so, the constancy of a condenser built on this "series complementary gap" principle is greater than that of the ordinary "parallel complementary gap" condenser as can be shown by taking, as an example, the simple variable condenser of three fixed plates and two moving plates of Fig. 9.

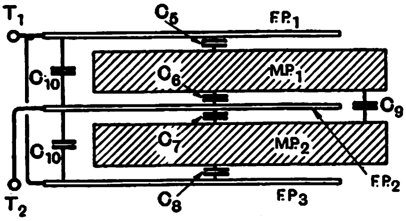
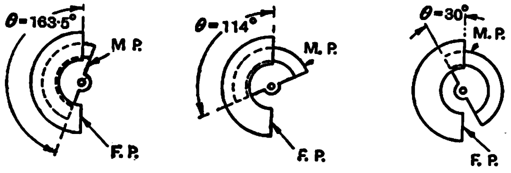


Fig. 9.

The Extent of the Errors introduced by the Capacity between adjacent Moving Plates.

Since the effect of the inter-moving plate capacity C_9 becomes increasingly serious as the capacity of the condenser is reduced, it is necessary to determine the change of capacity due to axial displacement of moving plates for various angular positions "θ" of the latter; thus three cases have been chosen :—



Case I. Case II. Case III.

(I) Moving plates interleaved with fixed plates throughout an angle "θ" of 163.5 *degrees,* i.e. *nearly maximum capacity* (180°).

(II) Moving plates interleaved with fixed plates throughout an angle "θ" of 114 *degrees.*

(III) Moving plates interleaved with fixed plates throughout an angle of only 30 *degrees.*

In order to make the example quantitative the capacity C_5, when equal to C_6, for the full 180 degrees of intercalation will be taken as $109\mu\mu F$, and the capacity C_9 between adjacent moving plates at the minimum setting of the condenser (zero intercalation), $54.5\mu\mu F$. The ratio between these capacities has been purposely made to represent the worst possible condition when the fixed plate thickness is zero.

The capacities $C_5\,C_6\,C_7\,C_8$ and the capacity C_9 are determined for the three cases thus :—

CASE I. $\theta=163.5°$

$$C_5=C_6=C_7=C_8=\frac{dC}{d\theta}\times\theta=\frac{109}{180}\times163.5$$
$$=100\mu\mu\text{F approx.}$$

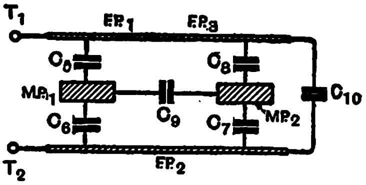


Fig. 10.

$$C_9=\frac{dC'}{d\theta}\times(180-\theta)=\frac{54.5}{180}\times(180-163.5)$$
$$=5\mu\mu\text{F}.$$

CASE II. $\theta=114°$.

$$C_5=C_6=C_7=C_8=\frac{109}{180}\times114$$
$$=70\mu\mu\text{F approx.}$$
$$C_9=\frac{54.5}{180}\times(180-114)=20\mu\mu\text{F}.$$

CASE III. $\theta=30°$

$$C_5=C_6=C_7=C_8=\frac{109}{180}\times30$$
$$=18\mu\mu\text{F approx.}$$
$$C_9=\frac{54.5}{180}\times(180-30)=45\mu\mu\text{F approx.}$$

The capacity C_{10}, although not constant with all values of θ, remains constant for any given value of θ, being unaffected by axial displacement of the moving plate system and can, therefore, be ignored in calculating the capacity *changes* due to this mechanical imperfection. Values for C_{10} will, however, be required later in order to express the changes of capacity as percentages of the total capacity of the complete condenser.

The five remaining elementary capacities may be redrawn as a bridge network, as shown in Fig. 11.

In the ideal condition when $C_5=C_6=C_7=C_8$ the resultant capacity C_R between T_1 and T_2 is simply equal to one of these elementary capacities, but when, due to an axial displacement of the moving plate system,

$$C_6=C_8>C_5=C_7$$

the resultant capacity C_R is best determined by adopting Maxwell's theory of networks in which I_1, I_2 and I_3, of Fig. 11, are hypothetical cyclic currents.

Employing these cyclic currents three simple equations may be formed :—

$$\frac{1}{\omega}\left(\frac{1}{C_7}+\frac{1}{C_8}\right)I_1-\frac{1}{\omega}\left(\frac{1}{C_7}\right)I_2-\frac{1}{\omega}\left(\frac{1}{C_8}\right)I_3=E \quad (1)$$

$$-\frac{1}{\omega}\left(\frac{1}{C_7}\right)I_1+\frac{1}{\omega}\left(\frac{1}{C_6}+\frac{1}{C_7}+\frac{1}{C_9}\right)I_2-\frac{1}{\omega}\left(\frac{1}{C_9}\right)I_3=0 \quad (2)$$

$$-\frac{1}{\omega}\left(\frac{1}{C_8}\right)I_1-\frac{1}{\omega}\left(\frac{1}{C_9}\right)I_2+\frac{1}{\omega}\left(\frac{1}{C_5}+\frac{1}{C_8}+\frac{1}{C_9}\right)I_3=0 \quad (3)$$

These equations can be simplified by eliminating the angular velocity thus :—

$$\left(\frac{1}{C_7}+\frac{1}{C_8}\right)I_1-\left(\frac{1}{C_7}\right)I_2-\left(\frac{1}{C_8}\right)I_3=\omega E \ldots \quad (4)$$

$$-\left(\frac{1}{C_7}\right)I_1+\left(\frac{1}{C_6}+\frac{1}{C_7}+\frac{1}{C_9}\right)I_2-\left(\frac{1}{C_9}\right)I_3=0 \quad (5)$$

$$-\left(\frac{1}{C_8}\right)I_1-\left(\frac{1}{C_9}\right)I_2+\left(\frac{1}{C_5}+\frac{1}{C_8}+\frac{1}{C_9}\right)I_3=0 \quad (6)$$

from which I_1 can easily be found and the resultant capacity

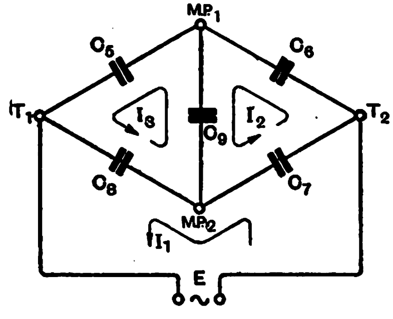


Fig. 11.

$$C_R=\frac{I_1}{\omega E}$$

and by making ωE equal to unity C_R is directly obtained because

$$C_R=I_1$$

The lowest value of C_R is, in each case, that obtained when all four elementary capacities are equal

$$C_R = C_6$$

the greatest value of C_R is, in each case that

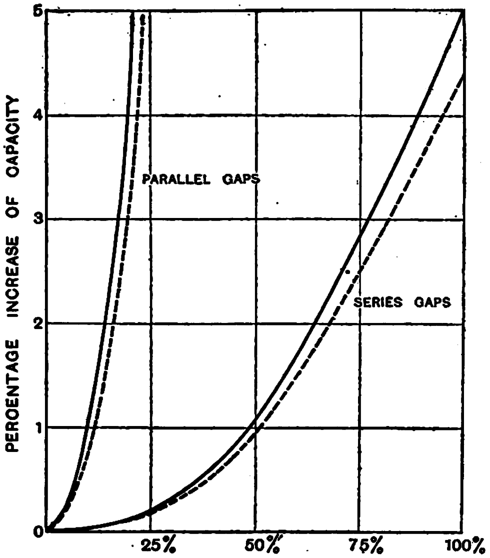


Fig. 12.

reached when

$$C_6 = C_8 = \propto$$

then C_5 and C_7 are reduced to 0.5 of their original mid-position values and the resultant capacity becomes

$$C_5 + C_7 + C_9$$

or, in other words, the capacity of the whole system cannot, even for the maximum axial displacement of moving system, increase by more than the amount of C_9.

In addition to these two limiting values of C_R, other intermediate values have been computed, by forming and solving three equations, (4), (5) and (6), for each of the three cases of the example and the results are given in the Tabulation A below and are shown in the full line curves of Figs. 12, 13 and 14. These curves show the post-calibration capacity increase due to an axial displacement of the moving plates relative to the fixed plates assuming that all dielectric gaps have been equalised at the time of calibration. In the same figures are given, for comparison, curves showing the corresponding capacity changes which would be experienced under the same conditions if the adjacent dielectric gaps were in parallel instead of in series. It will be observed that, although the possibility of capacity change becomes more serious for lower capacity settings, it is always less serious than in ordinary parallel gap condensers, for which the theoretical limit of infinity capacity is reached (although not smoothly) by a short-circuiting of the moving and fixed plate systems.

The tabulated figures below and the full

TABULATION A.

Case.	θ degrees.	C_9 $\mu\mu$F.	Axial displacement of moving system. %	$C_5=C_7$ $\mu\mu$F.	$C_6=C_8$ $\mu\mu$F.	C_R $\mu\mu$F.	Increase of C_R %	Corresponding increase of capacity of ordinary condenser. %
I.	163.5	5	0	100	100	100	0	0
			25	80	133.3	100.2	0.2	6.7
			54	65	217	101.3	1.3	40
			100	50	∞	105	5.0	∞
II.	114	20	0	70	70	70	0	0
			27.5	55	96.4	70.8	1.2	8
			55.5	45	157.3	75.6	8.0	45
			100	35	∞	90	28	∞
III.	30	45	0	18	18	18	0	0
			28	14	25.2	19	5.5	8.5
			64	11	50	25.3	40	70
			100	9	∞	63	250	∞

line curves of Figs. 12, 13 and 14 need correction for varying values of minimum or residual capacity. In the case of the ordinary parallel gap condenser the percentage capacity change corrections are small, due to the low value of residual capacity, but become very appreciable at the lower capacity settings if a fixed value condenser is paralleled with the variable condenser for the purpose of range limiting. In the case of the series gap condenser the residual capacity is *always*, due to its design, an appreciable proportion of the total capacity and corrections therefore become necessary irrespective of independent augmentation of minimum capacity. In order to find the *total* value of capacity at any angle θ it becomes necessary to determine C_{10} as previously mentioned and to do this the moving plate thickness has to be fixed, and this will, in turn, be fixed by the ratio of maximum to minimum capacity.

TABULATION B.

CASE.	θ degrees	Axial displacement of moving system. %	C_{10} unaffected by axial displacement. $\mu\mu$F.	C_R from Tabulation A. $\mu\mu$F.	Total capacity $C_R + C_{10}$ $\mu\mu$F.	Increase of total capacity. %	Corresponding increase of capacity of ordinary condenser. %
I.	163.5	0	13	100	113	0	0
		25		100.2	113.2	0.18	5.5
		54		101.3	114.3	1.15	25
		100		105	118.0	4.4	∞
II.	114	0	19	70	89	0	0
		27.5		70.8	89.8	0.9	7
		55.5		75.6	94.6	6.3	30
		100		90	109	22.5	∞
III.	30	0	29	18	47	0	0
		28		19	48	2.1	3.2
		64		25.3	54.3	15.5	25
		100		63	92	96	∞

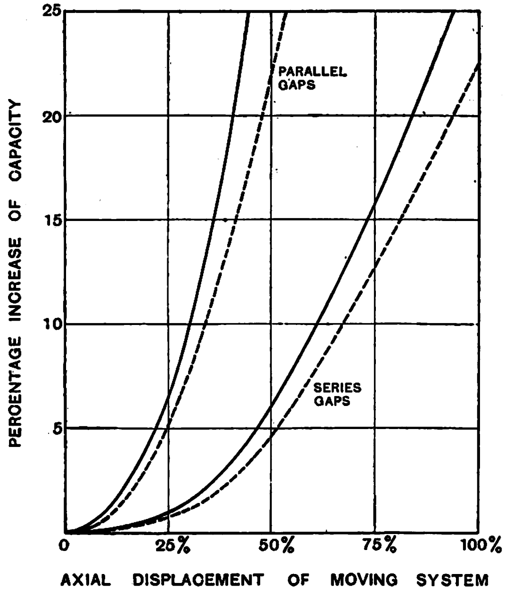


Fig. 13.

Assuming therefore a 5 to 1 ratio of effective dielectric gaps :—

$$d_5 = 5(d_3 + d_4)$$

and

$$\frac{dC''}{d\theta} = 0.2\left(\frac{dC}{d\theta}\right)$$

The unaffected capacity C_{10} consists of two parts in parallel :—

(*a*) That between those portions of adjacent fixed plates which are ***always*** exposed due to their being outside the radius of the moving plates. This component of C_{10} is constant and may be, perhaps, 10 per cent. of the maximum capacity $C_{max.}$; and

(*b*) That between the portions of adjacent fixed plates which are exposed upon the withdrawal of the moving plates. This component of C_{10} varies with θ and, for the example under consideration, is equal to

$$0.2\frac{dC}{d\theta}(180-\theta)$$

$$\therefore \quad C_{10}=0.1C_{max.}+0.2\frac{dC}{d\theta}(180-\theta)$$

CASE I.

$$C_{10}=(0.1\times 109)+0.2\frac{109}{180}(180-163.5)$$
$$=13\mu\mu\text{F nearly.}$$

CASE II.

$$C_{10}=(0.1\times 109)+0.2\frac{109}{180}(180-114)$$
$$=19\mu\mu\text{F}.$$

CASE III.

$$C_{10}=(0.1\times 109)+0.2\frac{109}{180}(180-30)$$
$$=29\mu\mu\text{F}.$$

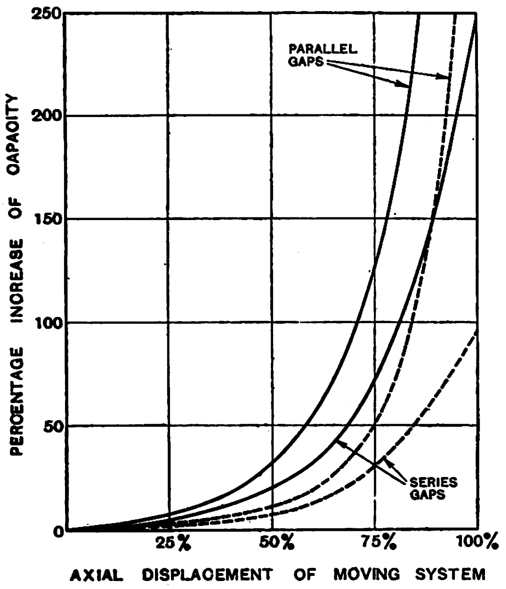


Fig. 14.

These values must be added to those of C_R of Tabulation A in order to obtain the full values of C in each of the three cases. This has been done in Tabulation B, which gives, in the seventh column, the percentage increase of total capacity for various axial displacements of moving system for each of the three cases. In order to provide a fair comparison between this and an ordinary parallel gap condenser the corresponding percentage capacity changes which would occur in such a condenser having the same ratio of maximum to minimum capacity have been computed and tabulated in the final column. These corrected percentage capacity changes which occur in both types of condenser are plotted for the three cases in Figs. 12, 13 and 14 (dotted curves).

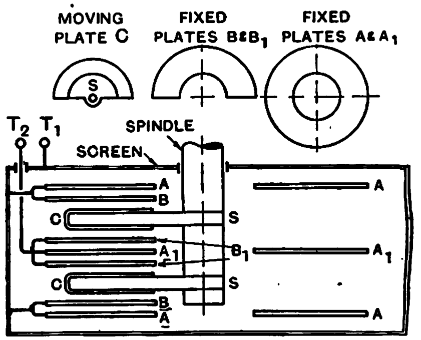


Fig. 15.

These curves have been plotted for exaggerated values of plate displacement in order to include the interesting limiting values, but the actual quantities involved in the case of a variable air condenser of precision quality are those, of course, of Fig. 3 of the first part of the article.

The Elimination of C_9—the Final Design.

In order however, to make full use of this principle of series complementary gaps an entirely different design has to be adopted in which the capacity C_9 is completely eliminated. In this design each intermediate moving plate, in addition to being entirely insulated from all other conductors, is completely screened from the field of all other moving plates. One method of accomplishing this is indicated diagrammatically in the sketches of Figs. 15 and 16.

In Fig. 15 the fixed semi-circular plates BB form the conductors of one terminal system and the exactly similar plates B_1B_1 form the conductors of the other terminal system. These plates are shaped as shown in the detail. The intermediate moving plates CC are formed by semi-circular supports or vanes of insulating material the outer portions of which are metal encased in order to produce an effective reduction of the gap between two adjacent fixed plates upon its insertion between them. These moving plates may conveniently take the form of silvered glass plates or "Keramot" (loaded ebonite) plates foil coated, or plated. Whatever form these moving plates take, however, the design must be such that dielectric losses in the insulating portions of them is negligible. Since both surfaces of the metal coating of the plates are at the same potential there is no field through the insulating support due to its own conductor but, if this conducting casing does not entirely enclose all the insulating material which is inserted between the adjacent fixed plates, there will be a loss-producing field between the latter. If, on the other hand, the metal coatings of the moving plates extend radially toward the spindle, beyond the boundaries of the fixed plates the constancy destroying intermoving plate capacity will be present. In order that neither of these objectionable features may be introduced, the metal portions of the moving plates are limited radially so as to not quite reach the boundaries of the fixed plates as shown in the sketch, so that field concentration at the inner edges of adjacent moving and fixed plates will prevent an appreciable field from passing from B to B_1, through the insulating support S while still eliminating appreciable capacity between adjacent moving plates CC.

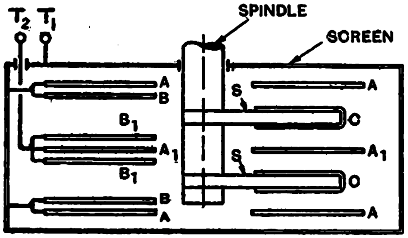


Fig. 16.

It would, perhaps, be safer to employ moving conductors of solid metal such as duralumin fitted to central insulating hubs in order to remove entirely the risk of a change of plate thickness at any point of the plate area since the whole principle depends upon this constancy and uniformity of plate thickness. If a solid metal moving conductor be employed, the only change of dielectric air gap dimensions (apart from a negligibly small change due to the expansion of the metal with temperature—a change for which partial compensation may be made by employing metals with slightly differing coefficients of linear expansion) is that due to a tilting, sagging or twisting of the conductor itself or of its insulating hub.

An imperfection of this nature may be represented by the angle between the planes of moving and fixed conductors; the secant of the angle giving the increase of effective moving plate thickness (normal to the surfaces of the fixed plates) and the cosine of the same angle giving the effective reduction of its radial dimension in a plane parallel to those of the surfaces of the adjacent fixed plates. These two changes tend, respectively, to increase and decrease the capacity at a given scale setting, the resultant tendency to capacity change due to this cause, even for angles of 30′ to 1° being less than 1 part in 10,000.

In order to prevent capacity between these portions of the moving plates which are not enclosed by the fixed plates between which they are rotating, the former are screened from one another by the additional conducting rings AA and A_1 which are connected electrically to appropriate terminal systems as shown. Whatever, therefore, the angular position of a moving plate it is *always* effecting a reduction of the dielectric gap between adjacent and oppositely connected fixed plates and in order that the increase of capacity with rotation of the moving system shall be large the distance between two adjacent semi-circular fixed plates B and B_1 must, of course, be appreciably smaller than that between two adjacent rings A and A_1.

In Figs. 15 and 16 all the semicircular plates have, for simplicity, been shown on the same side of the spindle. In practice, however, it is advisable to balance the moving system by fixing alternate moving plates to the spindle displaced relatively through 180 degrees. This is made possible owing to the fact that the conducting rings A and A_1 completely screen successive condenser elements enabling them to be built up alternately on opposite sides of the spindle. The whole system of fixed conductors, upon the geometrical permanence of which the electrical permanence of the entire condenser alone depends, is, due to this symmetrical building, made very rigid, it having a large base area for its mounting pillars and its complete conducting rings serving to brace the whole structure at numerous points.

The Capacity Change Obtained.

With this design of condenser it is, of course, impossible to obtain a great capacity change, but this becomes a real advantage when the condenser is to be used for precision wavemeter work, because it renders unnecessary the usual "zero" augmenting capacity which is in this case a fixed value *air* condenser of very rigid construction and having a *large air gap*—the ideal residual capacity.

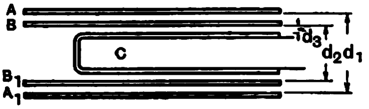


Fig. 17.

A usual value for the ratio of maximum to minimum capacity of a good quality variable air condenser (when its metallic screen is connected electrically to its low potential system) is 12 to 1, but, in order to open out the wavelength (or frequency) scale of the instrument and in order that *very small* capacity changes due to disposition of apparatus, leads, near-by conductors and operator may be rendered less important, this ratio is usually limited to about 2 to 1 in precision wavemeter design.

It is possible to obtain a capacity ratio of this order with this new design without increasing unduly the bulk of the condenser.

If d_1, Fig. 17, is the distance between two adjacent complete rings A and A_1;

d_2 is the distance between two adjacent semi-circular fixed plates B and B_1; and

d_3 is the distance between a fixed plate and the adjacent surface of an adjacent moving plate C.

Then the minimum capacity (at 0 degrees)

$$\propto \frac{1}{d_2} + \frac{1}{d_1 - d_2 + 2d_3}$$

and the maximum capacity (at 180 degrees)

$$\propto \frac{1}{d_1} + \frac{1}{2d_3}$$

$$\therefore \text{ Capacity ratio } \frac{C_{180}}{C_0} = \frac{\dfrac{1}{d_1} + \dfrac{1}{2d_3}}{\dfrac{1}{d_2} + \dfrac{1}{d_1 - d_2 + 2d_3}}$$

$$= \frac{2d_3 + d_1}{2d_1 d_3} \times \frac{d_2 (d_1 - d_2 + 2d_3)}{d_1 + 2d_3}$$

$$= \frac{d_2 (2d_3 + d_1)(d_1 - d_2 + 2d_3)}{2d_1 d_3 (d_1 + 2d_3)}$$

$$= \frac{d_2 (d_1 - d_2 + 2d_3)}{2d_1 d_3}$$

The smallest practicable dimension d_3 is about 40 mils., and assuming this, the expression for capacity ratio becomes :—

$$\frac{d_2 (d_1 - d_2 + 80)}{80\, d_1} \quad .. \quad (7)$$

It is obvious that d_2, in order to obtain a good effective gap reduction, must be about six times as great as d_3 and for various values of this order the ratio obtained has been computed from (7) for various values of d_1—the results being shown in the curves of Fig. 18.

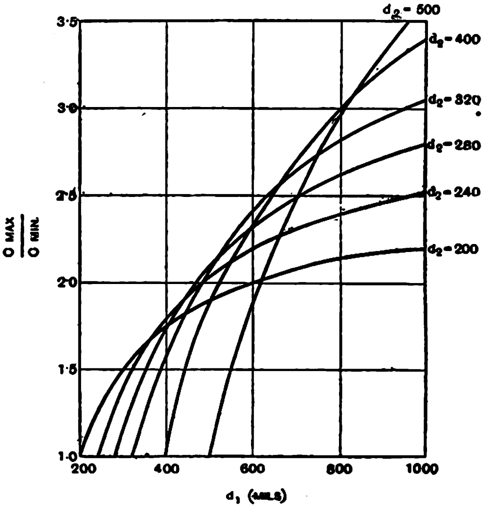


Fig. 18.

From these curves it will be seen that it is not always advisable, from considerations of bulk, to take advantage of the extra ratio obtained with high values of d_1 and so, choosing a value of 480 mils. for d_1, and a value for d_2 of 240, it is easily seen that this design of condenser has, for a given bulk, a maximum capacity of only

$$0.5\left\{\frac{480+40}{40\ +40}\right\}$$

that of an ordinary condenser having the same actual dimension of gap between moving and fixed plates; a plate thickness of 0.04 inch being assumed in each case.

Compared with an ordinary condenser, therefore, the product of the plate area and the total depth of bank of plates must be

$$2\left\{\frac{480+40}{40\ +40}\right\}$$

= 13 times greater, for a given capacity; the bank depth must be $\sqrt[3]{13}$ greater and the moving plate radius $\sqrt[3]{13}$ greater.

In practice, however, in order to aim at calibration constancy in an ordinary condenser of precision grade the dielectric air gap would have to be at least three times that of the example of new design given here and so the volume comparison ratio would be reduced from 13 to about 4 due to this —the linear dimension ratio being $\sqrt[3]{4}$.

If the capacity of the condenser to be designed is not of a very high order a greater value of d_1 is permissible (if the capacity is halved, d_1 may be doubled for a given bulk) and a higher value for d_2 chosen. Thus, if for a 0.001μF condenser a value for d_1 of 480 mils. is found to be the maximum permissible, d_2 can be fixed at anything between 240 mils. and 320 mils. without affecting the capacity ratio which would be about 2 to 1. For a condenser of only 0.0005μF capacity d_1 can be increased to 960 mils. without increasing the bulk, the capacity ratio can now be increased to over 3.5 to 1 by increasing d_2 to 500 mils. Series gap variable condensers of this type are, therefore, more easily designed to have large capacity ratios if their actual values are of a lower order.

The Complete Capacity Formula.

The ratios of $C_{max.}/C_{min.}$ given by the curves of Fig. 18 represent the maximum possible ratios obtainable and those obtained in practice may be slightly less due to the constant mutual exposure of the outer portions of adjacent fixed plates if such areas are present in the design to any appreciable extent and it will therefore probably be as well to form a complete expression for the capacity of the condenser at any scale setting.

Let r_1 be the inner radius of both fixed and moving plates,

r_2 be the outer radius of the moving plates,

and r_3 be the outer radius of the fixed plates,

then, expressed in the form $C=NKA/4\pi t$, the capacity of the complete condenser in $\mu\mu$F may be stated as the sum of the six capacities corresponding with the numbered areas of Fig. 19.

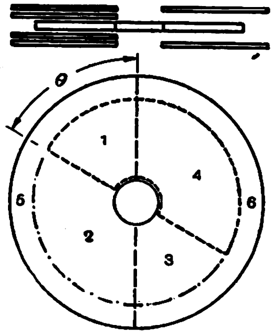


Fig. 19.

Thus

$$C=\left\{\frac{1.\dot{1}A_1}{4\pi(2d_3)}+\frac{1.\dot{1}A_2}{4\pi d_2}+\frac{1.\dot{1}A_3}{4\pi d_1}\right.$$
$$\left.+\frac{1.\dot{1}A_4}{4\pi(d_1-d_2+2d_3)}+\frac{1.\dot{1}A_5}{4\pi d_2}+\frac{1.\dot{1}A_6}{4\pi d_1}\right\}N$$

where

$$A_1=A_3=\frac{\pi\theta}{360}(r_2^2-r_1^2)$$

$$A_2=A_4=\frac{\pi(180-\theta)}{360}\{r_2^2-r_1^2\}$$

$$A_5=A_6=\frac{\pi}{2}(r_3^2-r_2^2)=\text{constant}$$

and N = number of *moving* plates.

This gives a simplified expression :—

Capacity (in $\mu\mu$F)

$$= 7.72 \times 10^{-4}.N\left\{k_1\theta\left(\frac{1}{2d_3}+\frac{1}{d_1}\right) + k_1(180-\theta)\left(\frac{1}{d_2}+\frac{1}{d_1-d_2+2d_3}\right) + 180k_2\left(\frac{1}{d_2}+\frac{1}{d_1}\right)\right\} \quad (8)$$

where N = number of *moving* plates

$k_1 = \{r_2^2 - r_1^2\}$

$k_2 = \{r_3^2 - r_2^2\}$

Screening.

In the diagrammatic sketch of Fig. 15 the condenser is shown completely screened. This is, of course, absolutely necessary in a variable condenser of precision quality and no complications are introduced by its use, because the screen may be joined electrically to one fixed plate system the plates of which can therefore be mounted rigidly and simply to the metallic case of the condenser without insulation. The other fixed plate system is mounted on small pieces of silica-quartz or pyrex in order to ensure relative geometrical permanence of the two fixed plate systems. The additional capacity due to the introduction of the screen merely augments still further the residual or "zero" capacity of the condenser and, in the diagram of the simple five plate condenser (Fig. 10), merely results in a slight increase in the value of the elementary capacity C_{10}.

The "Shorting" of Adjacent Plates.

It is seen, therefore, that the complete screened condenser will not have its electrical permanence or law conformity impaired by any irregularity of rotation of the moving plates, nor by any change in their positions axially provided that the bearing is good enough to prevent them from actually touching the fixed plates to which they are adjacent. No alteration of capacity would, of course, take place if a moving plate actually touched one of its adjacent fixed plates throughout the whole of the area of its intercalation, but this could only occur if the moving plate revolved in *exactly* the plane of the fixed plate and in practice this would not be the case. If an axial movement of the moving system were present to such an extent as to permit the touching of a fixed plate by a moving plate, the contact would probably only occur over a portion of the total area of intercalation and the remainder would consist of a thin air gap which would be, in effect, short-circuited by the portion in contact and in this way an alteration of capacity would be effected. Axial movements and rotation irregularities amounting to, say, 10 per cent. or 20 per cent. of the total dielectric air gap will not, in this condenser, produce any change of capacity, whereas similar defects in an ordinary parallel gap condenser would *completely* destroy its calibration.

An Electrical Complication and a Simplification.

An electrical complication which tends to impair very slightly the permanence of the condenser is introduced if the insulating supports or vanes of the intermediate moving plates are mounted on a metal spindle. This spindle will be joined electrically, through its bearing, to the earthy fixed plate system and the complete electrical system can be represented by redrawing the diagram of Fig. 10 to include the metallic mass S_1 as shown in Fig. 20.

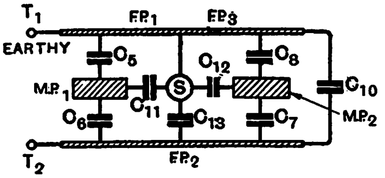


Fig. 20.

It will be seen that the additional capacity C_{13} merely makes a further contribution to the residual capacity of the condenser but the capacities C_{11} and C_{12} are added to the capacities of C_5 and C_8 respectively. Since these moving plate to spindle capacities are constant they tend to prevent the complementary changes of reactance of the series gaps C_5 C_6 and C_7 C_8 upon which the whole principle of constancy depends.

These unwanted capacities C_{11} and C_{12}, however, may be made, in practice, small enough to be negligible, and, moreover, if the spindle be made from an insulating material they disappear completely. But it should be noted that any capacity to moving plates which is, for any given angular position of the moving plates, constant and unaffected by an axial movement of those plates, militates against the permanence of the condenser, and in order to ensure that such unwanted capacities are reduced to negligible proportions the moving plate conductors should be well enclosed by the fixed plate conductors and well away from all other conducting surfaces.

The notes on this special design of variable air condenser would not be complete without mention being made of the incidental simplification of the elimination of a flexible connection or wiping contact to the moving plate system. This feature affords great relief to the condenser designer since, even by exercising the utmost care and ingenuity, it is difficult to obtain, with any one device, all the essential qualities of low and constant effective resistance, low and constant inductance, freedom from noise when used in oscillating circuits, and mechanical reliability with much rotation of moving system.

Conclusion.

In conclusion some idea should, perhaps, be given of the accuracy at which one would aim when designing a sub-standard wavemeter employing this new condenser. In the introduction it was stated that the accuracy should be greater than 1 part in 1000 and with ordinary condensers this is not easy. By employing the new design, however, it is hoped to obtain a frequency accuracy of 1 part in 10,000, corresponding with a capacity inaccuracy of the order 2 parts in 10,000. In addition to the possibilities of inaccuracy already discussed, there are several others which have to be considered carefully before stating a figure of overall accuracy of this order.

For instance, it is just possible that some special means for reading or setting the angular position of the moving system to this degree of accuracy would become necessary. It will, however, be found that a finely divided degree scale of about seven inches radius and having main divisions at 0.5 degree intervals and a 10 division vernier covering 4.5 degrees will be sufficient for the required accuracy of reading, in a condenser having a 2 to 1 capacity ratio.

Another possible cause of an inaccuracy of the order we are now considering is the dimensional change of the scale. A metal scale will be found to have a sufficiently low temperature coefficient of linear expansion to render temperature changes negligible.

There are, of course, numerous possible constructional causes of inaccuracy to be considered—minor mechanical imperfections which were small enough to be negligible in ordinary variable condensers but which now, in the new design, may become limiting factors in view of the fact that the major mechanical imperfections have, by a changed electrical scheme, been rendered unimportant. These are rather outside the scope of the present article and their correction may be left to the ingenuity of the designer and to the conscience of the instrument maker.

There is, however, one other very important aspect to be considered—that of resonance detection. Flatness of tuning must not limit the accuracy of reading and in order that the detection of resonance shall be sufficiently sharp to prevent this the decrement of the whole sub-standard should be not greater than the order 0.006 to 0.008. If the inductances are designed to this efficiency, changes in resonant voltage or current of the order 0.5 per cent. will be obtained by detuning by 2 parts in 10,000 in capacity (1 part in 10,000 in frequency) and these changes are within the limits of simple detection by the two reading method.

In order to keep the *total* decrement down to the required low order it is essential that the contribution to it by the detector shall be not greater than, say, 0.001. This fact demands the utmost care in the choice of a method by which to associate the detector with the simple resonant circuit. Two *direct* methods are frequently employed, the thermo-junction galvanometer for the detection of resonant current or the simple thermionic voltmeter for voltage indication of resonance. Neither of these direct methods can, however, be employed throughout the whole band of useful wavelengths. The thermo-galvanometer method may be safely employed on the longest wavelengths with a heater resistance of 1.0 Ω when the inductance is not less than 20,000μH. With values of inductance less than this a heater of lower resistance must be used, but even with a 0.1 Ω heater the method cannot be employed for values of inductance less than

100μH. It should be noted, also, that with this method, if for greater accuracy the L/C ratio is decreased, the decrement augmentation by the detector is increased.

On the other hand the thermionic voltmeter method may be employed with safety on the ultra-short waveband even if shunted across points having the full potential difference between them. The effective resistance of a thermionic voltmeter is of the order $0.75 \times 10^6 \Omega$ and for this value of shunt resistance it will be seen that this method cannot be employed with inductances greater than 25μH without increasing the decrement augmentation beyond the 0.001 limit.

The above figures have been computed taking as a basis a capacity ratio of 2 to 1 for each inductance of the wavemeter and a *minimum* capacity gradually ascending (with wavelength) from 250$\mu\mu$F to 1000 $\mu\mu$F throughout the whole useful waveband.

It will be seen that a gap occurs between 25μH and 100μH (at about 300 metres) where neither of these direct methods should be employed. The gap is small and can be bridged by adhering a little less rigidly to the limits of decrement, but its existence shows that an aperiodic inductively (loosely) coupled detector circuit (crystal and galvanometer) is very desirable, if not essential, for intermediate wavelengths of from, say, 100 to 1000 metres. Above 1000 metres the thermo-galvanometer may be employed with safety if the heater is of low resistance, and below 100 metres the thermionic voltmeter method is satisfactory.

A More Sensitive Method of Resonance Detection.

If the decrement of the circuit exceeds the limit given it will not be possible to obtain readings of the detecting instrument sufficiently accurately to give a frequency accuracy of 1 part in 10,000. Such a reading accuracy will in any case, even with circuits of the lowest possible decrement, be found difficult.

The difficulty is, of course, due to the changes of instrument reading required being very small percentages of the maximum reading at exact resonance. This trouble may be eliminated by employing two galvanometers of different sensitivities in a detecting circuit as shown in Fig. 21.

Resonance is first detected using the indication of the ordinary moving coil *pointer* microammeter G_1 having a range of about 20μA for a full scale deflection. G_2 is a much more sensitive galvanometer of the suspended moving coil *reflecting* type having a sensitivity of about, say, 150 millimetres per μA at a scale distance of one metre. This galvanometer is specially provided with a stop which prevents any deflection of the moving coil from zero in one direction, and a direct current of about, say, 10μA is arranged to flow in the galvanometer in the direction which will keep the coil hard up against this stop. The small potential for this purpose is obtained from a single cell and potential divider R_2, the resistance R_1 is required to preserve the correct (critical) resistance of the galvanometer circuit.

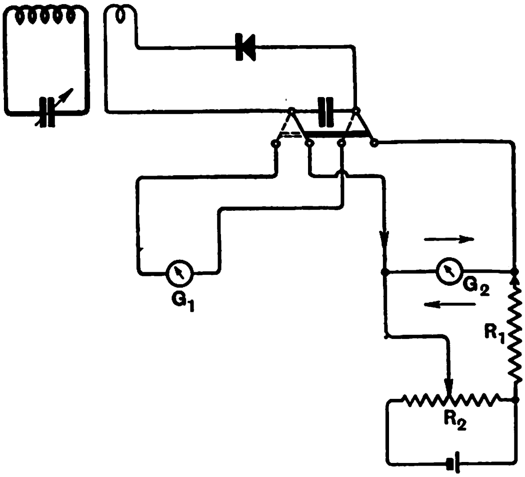


Fig. 21.

If resonance has been obtained on G_1 at about 11μA, upon switching over to G_2 a deflection of 150 millimetres from zero will be obtained for an increase of rectified current from 10μA to 11μA, while currents below 10μA will not deflect the coil from its stopped zero position. The potentials across the galvanometer due to the rectified current and to the initially applied direct current must, of course, be applied so as to oppose. If that due to the rectified current is not sufficient to produce a deflection of G_2 or is sufficient to produce a deflection greater than the scale length, a simple adjustment of the slider of R_2 to give a smaller or greater "deflection opposing" potential respectively must be made.

The whole arrangement is merely a scheme of magnification which allows the small changes of rectified current about resonance to be spread over the entire scale instead of occupying only a small portion of it; the less sensitive indicator is, of course, necessary in order to initially locate resonance with facility.

By this method a resonance curve of great apparent sharpness can be obtained. Such a curve is shown in Fig. 22 (G_2) for comparison with one obtained using the micro-ammeter (G_1). The points shown are actual readings taken on a circuit of high decrement (about 0.1) at a frequency of 10^6 and a resonant capacity of $400\mu\mu F$ and show a much greater accuracy of reading in the case of G_2 by all falling on a smooth curve.

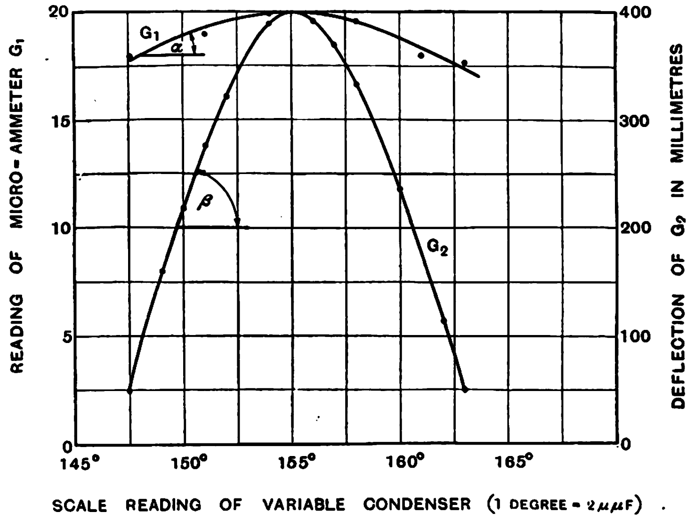


Fig. 22.

When employing the two reading method of resonance detection the accuracy of reading will be proportional to the tangents of the angles α and β (*i.e.*, to the "slope" of the curves) if the scale lengths of G_1 and G_2 are of the same order. But the reflecting galvanometer has a scale length usually about ten times that of the pointer instrument and so has an accuracy of detection

$$10 \frac{\tan\beta}{\tan\alpha}$$

times that of the latter. This scale length factor should, however, be reduced to about 2.5 on account of the loss of definition and steadiness of the "spot" of a reflecting galvanometer. This magnification factor in the case depicted here is about 20, which increases the accuracy *of detection* from 2.5 parts in 1000 to just over 1 part in 10,000.

A Novel Valve Detector.

By H. J. Neill.

IN the course of experimental work with resistance-coupled speech amplifiers it was found that the valves of the speech amplifier were overloaded, and that the overload could not be accounted for by electro motive forces of audible frequency. From this it appeared that the predetection frequency was present in the speech amplifier and must be eliminated. It was desired to retain a valve detector on account of its reliability and furthermore to use the lower bend of the anode current characteristic for detection. The detector was of course to be coupled by the resistance method to the first speech amplifying valve or else coupled through a filter, or by other means to pass to the detector valve unattenuated all frequencies up to about 12,000 cycles per second. The method of separating the intermediate frequency in a supersonic amplifier from speech frequencies is known and it can be shown that if the beat frequency is low a two or three-stage filter is necessary to effect adequate separation. Such a filter is not always easy to design and in every case is liable to objection. Up to the present, however, a filter has appeared to be inevitable with supersonic amplifiers working at any frequency above about 300,000 cycles per second.

A perusal of the Western Electric Company's patent specification No. 102,503 which relates to the transmission of one or both side bands only in high frequency telephony, led to the idea that similar methods could be used to eliminate the predetection carrier frequency in the detector.

The characteristic equation of a detector can be written

$$y=f(x)=a+bx+cx^2+dx^3+ex^4+\ \ldots \qquad (1)$$

It can easily be shown that the only terms in this expression which are useful to produce the frequency with which a carrier wave has been modulated are those terms having an even number index. Thus the terms cx^2, ex^4 etc., are the only terms useful from the detection point of view. The term bx produces only the original carrier frequency and the two side bands. The cubic term is likewise useless. The problem is therefore to eliminate the terms of odd powers. If we can treat the input in the manner represented by $f(x)+f(-x)$ it is clear that the terms of odd power disappear thus :—

$$\begin{aligned} y' &= f(x)+f(-x) \\ &= 2a+2cx^2+2ex^4+\ \ldots \qquad (2) \end{aligned}$$

The characteristic curve of a valve takes the form indicated in equation (1) where x represents the grid voltage and y represents the anode current. Two valves can be used together to fulfil the requirements of equation (2). In order to do this it is necessary to apply the same potential simultaneously to the grids of both valves, but positively to one and negatively to the other. The anodes of the valves must then be connected directly together and y' represents the current in the common lead to the anodes.

A typical circuit is shown in Fig. 1.

It will be seen that the grids of the two valves are connected to opposite ends of the closed oscillatory circuit and the anodes are fed from the battery through a common resistance R_1. The condenser C_1 for coupling the detector to the next valve is connected to the junction of the resistance and anode connections.

It must not be thought that this detector system eliminates all frequencies other than the desired modulation frequency. It does not. Currents of twice modulation frequency and also currents of frequencies higher than the carrier wave frequency will be present in the resistance R_1. If the fourth power term in equation (2) is not negligible there will also be other harmonics of the modulation frequency. In general, however, if the percentage modulation is not too high the modulation frequency current will predominate. In order to by-pass the high frequencies a condenser C_2 should be connected from the anodes to filaments as shown, but this condenser may in general be reasonably small so as not to by-pass any appreciable quantity of the upper modulation frequencies. In chronic cases of supersonic amplifiers when the beat frequency is very low, such as 30,000 cycles per second, it may be necessary to insert a simple single stage filter between the anodes and the coupling condenser. Although the arrangement has been described as making use of the bend of the anode current characteristic, grid rectification is equally applicable.

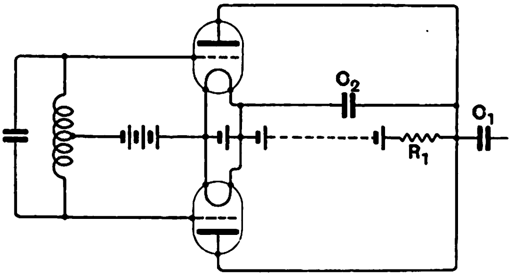


Fig. 1. *A valve detector circuit which requires the use of much less H.T. for a given input voltage than a normal circuit.*

The arrangement also has another advantage which is sometimes very useful, namely that it will deal with double the total input voltage that a single detector valve of the same type in the same adjustment can deal with. In certain circumstances this can be very useful. For example, at the author's station in London the amplitude of the signal from 2LO as applied to the grids is in the region of 23 volts. No high frequency amplification is used. The aerial tuning inductance is loosely coupled to the closed circuit shown in Fig. 1, and the total capacity of the closed circuit is about 90$\mu\mu$F. Using a single valve detector a grid bias of 25 volts and consequent large value of anode voltage was necessary. With the arrangement shown in Fig. 1 the grid bias is reduced to 12 volts and the high tension voltage approximately halved with no apparent loss of signal strength.

A further advantage of the system is that, as far as the high frequency side is concerned, it is electrically symmetrical about earth. This fact prevents the tuned circuit itself acting to a certain extent in the manner of an elevated aerial, though of course it does not prevent it picking up signals in the manner of a loop aerial. The latter method of pick up can be prevented by winding the inductance astatically and arranging the aerial inductance, or primary of transformer in the case of high frequency or supersonic amplifiers, to couple with it.

In conclusion it may be stated that the author prefers this arrangment both for supersonic amplifiers and for reception of the local station even though it necessitates the use of an extra valve. The reason for using the arrangement for reception of the local station is reduction in voltage of the high tension battery needed.

One precaution is necessary in putting the arrangement into practice, more particularly when using anode current rectification. It is necessary that the characteristics of the two valves should be very nearly identical, otherwise the benefits will only be secured in part or not at all. The author has found that the Cosmos " S.P.18 green spot " valve is extremely suitable on account of its high voltage factor. The characteristics of these valves, however, vary considerably from valve to valve, especially about the lower bend. Incidentally, in plotting the characteristics for comparison, the anode resistance R_1 should be included in the anode circuit with a good milliammeter having a scale of 0-2 milliamperes. A suitable value for R_1 when using the Cosmos valve is 100,000 ohms. The value of high tension supply will of course depend solely upon the amount of grid bias required to prevent the flow of grid current. This value of bias is determined by the signal amplitude which may be anything from a small fraction of a volt to 20 or 30 volts.

The value of high tension required may be calculated from the formula

$$V = -\mu V_g$$

where V is the approximate value of high tension,

V_g is the grid bias,

μ is voltage factor of the valve.

The voltage factor of the Cosmos valve is about 15. If the signal amplitude is 4 volts, which is a reasonable value to expect either from a local station or supersonic amplifier, about —1 volt bias will be required with the Cosmos valve, since grid current commences at about 1.7 volts and only half the signal voltage is applied to each grid. Consequently, in these conditions, about 15 to 20 volts is all the H.T. required. In conditions such as these " Q " valves are extremely suitable with a grid bias of — 2 volts and about 100-150 volts high tension. When " Q " valves are used the anode resistance R_1 should not be less than about 300,000 ohms and should preferably have double that value. The " Q " valve has a voltage factor of about 50 and consequently a very high impedance. Valves such as the " D.E.5B," although very satisfactory, are unnecessarily expensive for the purpose, especially as only a very small emission is required. The " Qx " and " D.E.Q." are quite satisfactory for larger inputs than the " Q " will deal with but are again expensive. The " Q " valve is, of course, expensive both in first cost and in filament consumption, but on account of its high voltage factor is very valuable for dealing with moderate signals. For supersonic amplifiers the " Q " valve is the best known to the author since the input signal amplitude fed to the second detector rarely exceeds 2 or 3 volts.

Valve Current from A.C. Mains.

Description of a Method employed by the Author.

By J. K. Jennings, M.Sc. Tech.

IN this article a method of obtaining H.T. and L.T. supplies for a receiving set is described.

The object has been to devise a cheap form of apparatus which can be constructed easily in the experimenter's room.

Apart from the convenience of the house mains as the source of energy for the set, in the method described running costs are very low and the initial outlay is not excessive. As every listener knows, battery expenses form the main item in the cost of running an ordinary set.

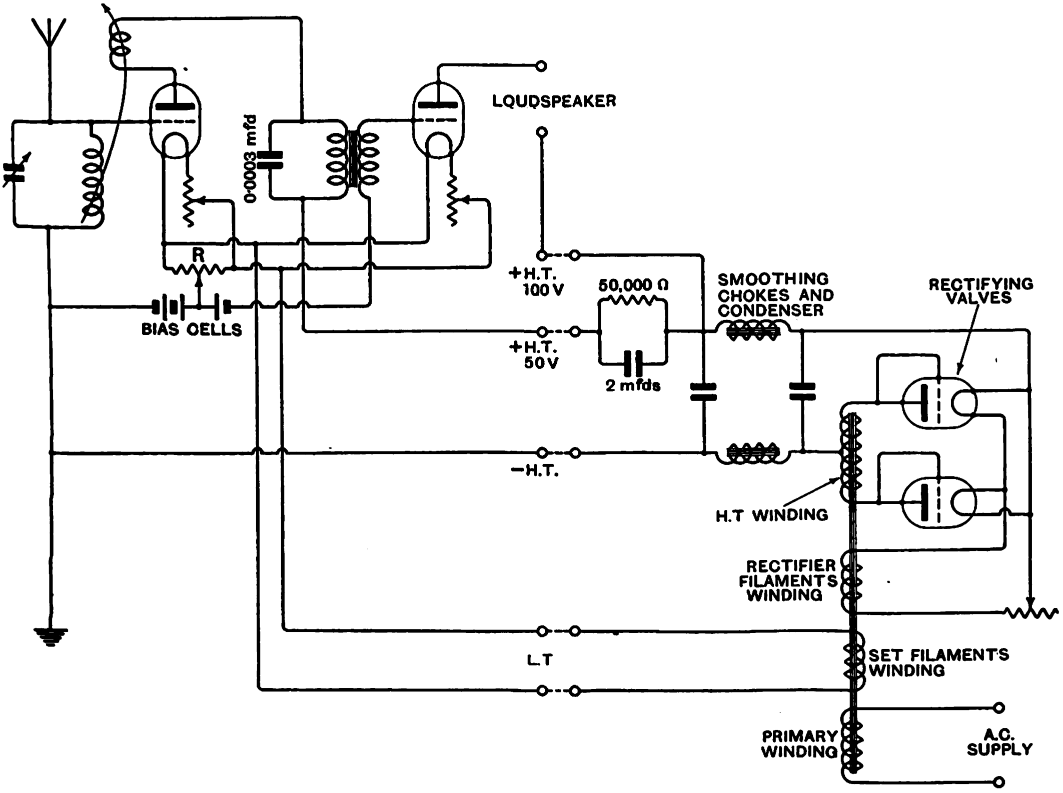


Fig. 1.—*The mains equipment circuit associated with a two-valve receiver.*

The Apparatus.

The L.T. supply for the set is obtained from a step-down transformer, the primary of which is connected to the house A.C. mains.

The H.T. supply is obtained from additional windings on the same transformer. It is proposed to use a valve rectifier for the latter supply.

A complete diagram of connections for a two-valve set is given.

In Fig. 1 the two-valve set is shown separated from the extra apparatus, which is conveniently mounted on a separate panel.

Notes on the Circuit.

The set itself is connected as an ordinary detector and L.F. circuit, except that anode rectification has been adopted in preference to the more usual grid condenser and leak method. The former arrangement enables the A.C. hum to be more easily reduced. The value of the bias on the detector may be up to about 8 volts negative.

In the diagram it will be noticed that a potentiometer *R* has been connected across the filaments of the valves of the receiver, and that the grid circuits of both valves are connected to the potentiometer slider. The object of this arrangement is to reduce hum. Hum is produced in two ways: first by the cooling of the filament and the resulting decrease in emission between each peak in the A.C. supply; secondly, by changes in P.D. between mean grid potential and average filament potential. To cure the latter trouble the arrangement described above is adopted, for by means of the potentiometer we can produce an accessible filament midpoint to which to "tie" the grid.

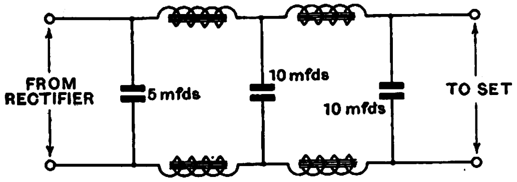


Fig. 2.

The hum caused by the cooling of the filament cannot be removed entirely, but may be reduced by using low temperature valves, and valves with large filaments.

Large condensers and chokes (Fig. 2) are necessary for smoothing out the output from the rectifying valves before connecting to the H.T. terminals of the set. The larger the smoothing system the less the hum.

Half Ford ignition coils make excellent chokes. Choke coils to be effective must be worked on the steep part of their magnetisation curves. This means that the number of ampere turns should not be sufficient to saturate the iron section used.

Readers will notice that the method gives only one value of H.T. For this reason a 50,000 ohm resistance, shown in the diagram, has been inserted to obtain reduced H.T. for the detector valve. The resistance must, of course, be shunted with a 2μF condenser.

It will be seen that the most important part of the work is the construction of the transformer.

The complete design and calculation of a transformer is given below to meet the stated conditions, so that readers may substitute other figures to suit their particular cases.

The Transformer.

The transformer must have four separate windings for the following purposes:—

1. The primary, for connection to A.C. mains.
2. For filament supply to the set.
3. For filament supply to the rectifier.
4. For H.T. supply to the rectifier.

Transformer Design.

Input—220 volts 50 cycles.

Output—

1. To set L.T., $7\frac{1}{2}$ volts 2 amps.=15 watts.
2. To rectifier L.T., $7\frac{1}{2}$ volts 2 amps.= 15 watts.
3. To H.T. supply, 220 volts across "outers."

Let average current to be passed through rectifying valves be 100 milliamps, then average current per side of H.T. winding is 50 milliamps.

$$\therefore \text{H.T. output} = \frac{50 \times \pi}{2\sqrt{2}} \times \frac{220}{1{,}000} = 12 \text{ watts.}$$

Approximate total output=50 watts.

Assume transformer efficiency=80 per cent.

Then input=65 watts.

Primary wattful current=0.3 amp.

As a first approximation we can take the full load primary current at 0.5 amp.

Estimation of Size of Transformer from Coil Cooling.

A current density of 140 amps per sq. cm. (900 amps per sq. in.) will be suitable provided the depth of winding is small.

This gives a cross section of wire of

$$\frac{\cdot 5}{140} = .00361 \text{ sq. cm.,}$$

and the nearest wire is No. 22 S.W.G. We shall use D.C.C. wire and allow 5 turns per volt.

$\therefore$ No. of turns on primary $= 220 \times 5 = 1{,}100$.

For D.C.C. wire add .03 cm. to the bare diameter; then overall diameter .101 cm.

Assume depth of winding $= 1.5$ cms.
Then

$$1{,}100 = \frac{1.5}{101} \times \frac{L}{.101}$$

where $L =$ length of coil.

$$\therefore \qquad L = 7.5 \text{ cms.}$$

Allow a length of 8 cms.

Then the transformer up to the present is as shown in Figs. 3 & 3a, if we assume we use a standard lamination one inch wide (2.54 cms.).

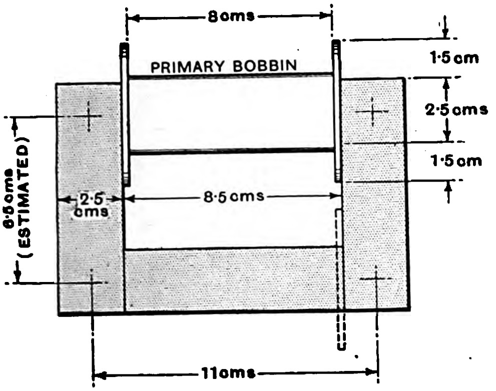


Fig. 3.

From the estimated sizes shown we find that the approximate length of iron path is 37 cms..

Iron Section.

Assume a 4 per cent. volt drop due to resistance of the primary, then induced volts $= 220 - 8.8 = 211.2$ volts.

$$211 = 4.44 \times N \times Qm \times f \times 10^{-8}.$$

where $N =$ number of turns
$Qm =$ maximum value of flux.
$f =$ frequency.

$$\therefore \qquad N \times Qm = .95 \times 10^{-8}.$$

At $N = 1{,}100$. $Qm = .865 \times 10^{-5}$ lines.

Allow a Bm of 10,000 lines per sq. cm.

At this value of B the amp turns per cm. length $= 8$ and magnetising current

$$= \frac{8 \times 37}{1{,}100} = .296 \text{ amps.}$$

This is very reasonable.

Then section of iron required

$$= \frac{.865 \times 10^5}{10{,}000} = 8.65 \text{ sq. cms.}$$

The depth of iron is then

$$\frac{8.65}{2.54} = 3.4 \text{ cms.}$$

Allowing 10 per cent. for paper or varnish, outside size of iron

$$= \frac{3.4}{.9} = 3.8 \text{ cms.}$$

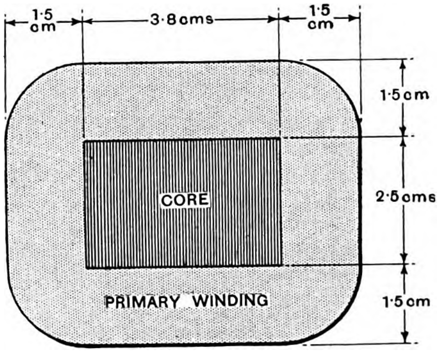


Fig. 3a.

Check Iron Loss.

At 50 cycles and 10,000 B_{max}. loss per cc. $= .033$ watt. Total volume of iron in core $= 37 \times 2.54 \times 3.4 = 320$ cubic cms.

Iron loss $= 320 \times .033 = 10.5$ watts.

In view of the fact that the total losses in the transformer must not exceed 15 watts this figure for iron loss is on the high side.

We are now in a position to estimate the I^2R loss in the primary and to see what cooling surface is available to dissipate this loss.

Length of wire $= 1{,}100 \times$ mean length of turn.

Mean length of turn

$$= (3.8 + 1.5) \times 2 + (2.54 + 1.5) \times 2$$
$$= 18.7 \text{ cms.}$$

Length of wire $=1{,}100\times 18.7=20{,}600$ cms.

$\therefore$ Resistance of primary $=8.78$ ohms.

Approx. $I^2R=(.5)^2\times 8.78$

$=2.2$ watts.

Cooling area of primary coil

$=8\times 5.5\times 2+8\times 6.8\times 2$

$=197$ sq. cms.

which gives 90 sq. cms. per watt, which is ample.

The iron and primary coil have now been dealt with.

The L.T. Coils.

The L.T. coils are similar in all respects. The output required is 7½ volts 2 amps. In these coils we can afford to raise the current density to 200 amps per sq. cm. because the winding will contain less insulation.

$$\text{Area of conductor} = \frac{2}{200} = .01 \text{ sq. cm.}$$

This area is very nearly met by No. 18 S.W.G. wire.

The diameter of No. 18 wire $=.122$ cm. bare with D.C.C. diameter $=.152$ cm.

$$\text{Number of turns necessary} = \frac{8}{211}\times 1{,}100$$
$$= 42 \text{ turns}$$

(allowing for .5 volt drop in the L.T. winding and leakage).

Assume depth of winding 1 cm.;

$$\text{then} \quad 42 = \frac{1}{.152}\times\frac{L}{.152}$$

where L = length of coil.

$$L = .97 \text{ cm., say 1 cm.}$$

A length of 1 cm. for each L.T. winding seems suitable.

The H.T. Winding.

It will be convenient to put the two L.T. windings and the H.T. winding on the same limb of the core. For this reason we shall, if possible, limit the length of H.T. winding to $8-(1+1+1.5)=4.5$ cms.

(The allowance of 1.5 cms. is for insulation between the windings.)

It will be remembered that this winding will have a middle tapping.

Volts across "outers" is to be 220.

$$\therefore \quad \text{Turns} = \frac{1{,}100\times 220}{211} = 1{,}140.$$

Add 10 per cent. for various drops.

This gives us 1,250 turns on the H.T. winding. R.M.S. current $=55$ milliamps.

Allow density of 150 amps per sq. cm.

$$\therefore \quad \text{Section of wire} = \frac{.055}{150} = .000368 \text{ sq. cm.}$$

No. 32 S.W.G. wire has a section .00059 sq. cm., and we shall, for mechanical reasons, use this.

Diameter of No. 32 wire $=.0274$ cm.; add .016 cm. for D.S.C., which gives .043 cm. as total diameter of wire.

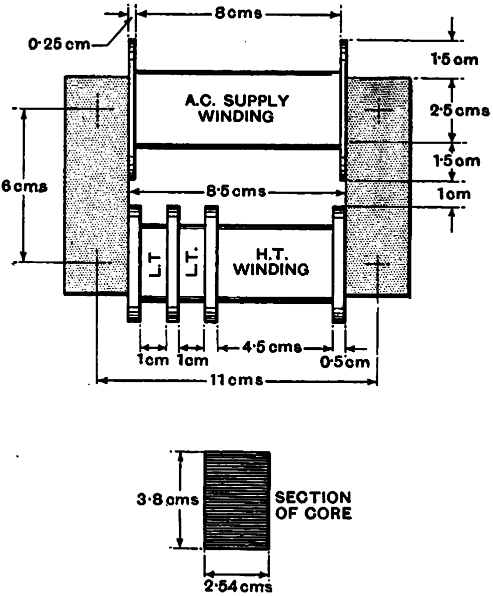


Fig. 4.

To find depth of winding D:—

$$\text{Then } 1{,}250 = \frac{4.5}{.043}\times\frac{D}{.043}.\ D=.514 \text{ cm.}$$

This depth is rather less than it need be, and D.C.C. wire could probably be used. Total diameter D.C.C. No. 32 wire $=.0574$ cm.

$$\text{Then} \quad D = \frac{1{,}250\times .0574\times .0574}{4.5}$$
$$D = .92 \text{ cms.}$$

which is quite suitable. We shall use D.C.C. wire.

Drop and Watts Lost in H.T. Winding.

Mean length of turn
$= (3.8 + .92) \times 2 + (2.54 + .92) \times 2$
$= 16.2$ cms.

Length of wire $= 1{,}250 \times 16.2 = 20{,}200$ cms.
Resistance = 58.3 ohms.
IR drop = 3.2 volts.
I^2R loss = .177 watt.

The cooling will be ample.

In the estimate made we allowed for a depth of winding of 1.5 cms. for the H.T. winding. Then we may now reduce the lengths of the cross limbs of the core to 6 cms. instead of 6.5.

The finished transformer core bobbin is is shown in Fig. 4.

A summary of the main sizes of transformer material is given below in tabular form, with lengths of wire and weights given in yards and ounces respectively :—

	Primary.	Set L.T.	Rectifier L.T.	H.T.
L'gth of bobbin	8 cm.	1 cm.	1 cm.	4.5 cm.
No. of turns	1,100	42	42	1,250
Size of wire	22 S.W.G.	18 S.W.G.	18 S.W.G.	32 S.W.G.
Length of wire	225 yds.	8 yds	8 yds.	220 yds.
Weight of wire	1 lb. 12 oz.	4 oz.	4 oz.	5 oz.

In Fig. 4 the bobbins are shown in position on the core legs, actually they must be wound before assembling in this way.

The core will consist of soft iron laminations 2.54 cms. wide (1 inch standard iron) and should be built up to 3.8 cms. when compressed. The weight of iron required will be about six lbs.

Half of the laminations should be cut into lengths of 8.5 cms., and the remaining half into equal numbers of lengths of 3.5 cms. and 13.5 cms.

Three sides should be built up as indicated in Fig. 5.

The bobbins may be made out of presspahn or fullerboard, 15 mils. thick, the layers and ends being well shellacked together and dried.

Readers will be well advised to make a wood former .2 cm. larger than the core size on which to shape the bobbin and wind the wire. The completed coil may then be slipped over the legs of the core easily.

The body of the bobbins may be made out of two thicknesses of the insulation, and the ends out of four or five thicknesses. Care should be taken to bring out the middle tap on the H.T. winding between two pieces of insulation.

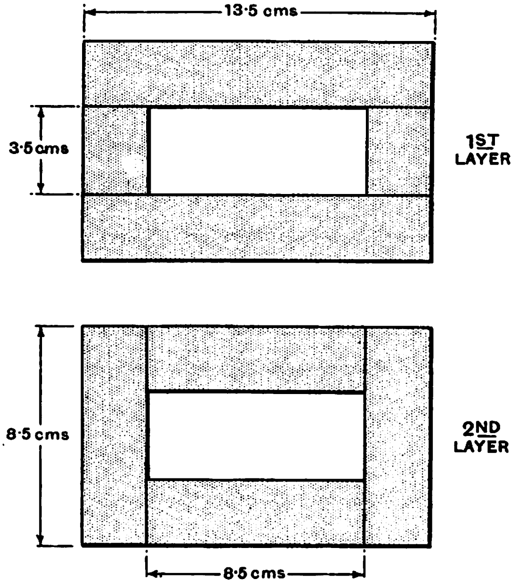


Fig. 5.

When the coils have been put on and the core finished off, two clamps should be fitted to the transformer core as shown in Fig. 6.

Readers should be careful to see that the bobbins are held tight on the core. This may be effected by inserting insulation at the ends of the bobbins after the transformer has been assembled.

The Rectifier and Lay-out of Apparatus.

The rectifier will consist of two power type valves, which may be conveniently mounted on a separate panel. In Fig. 1 the extra apparatus has been arranged apart from the original two-valve set, and the dotted lines between terminals represent external wires connecting the two units.

The potentiometer *R*, which should have a resistance of about 300 ohms, is shown in the original set. This arrangement is very convenient, and it should not be difficult to find room for this small component on the original panel.

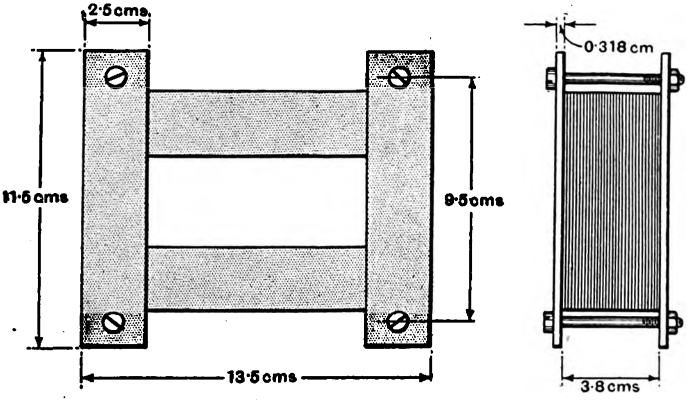


Fig. 6.

There are no special points about the rectifier and the complete diagram of connections (see Fig. 1) shows the wiring clearly. It will be noticed that the grids of the rectifying valves are connected to their respective plates in order to increase the available D.C. output. The insulation of the rectifier filaments winding on the transformer is important because this winding, and also the rheostat, are at the H.T. potential. The set will operate as with batteries as soon as the potentiometer *R* and the negative bias values have been adjusted.

It is hoped that the method described will prove of interest to other experimenters who are tackling the battery problem.

The Radiation Resistance and Energy Capacity of Half-wave Aerials.

By E. Green.

IN otherwise well-informed wireless circles there seems to be some ignorance of the properties of the antenna in use on short waves. Thus we find it stated in a recent manual that one of the difficulties on short waves is to get an appreciable power in the aerial owing to its small capacity. The real truth of the matter is exactly the reverse; it is on long waves that it is difficult to deal with large powers in the aerial, while on short waves it is comparatively easy. The normal type of aerial used in short wave work is a vertical wire, *XY*, about half a wavelength in length, the current and voltage distribution being as shown in Fig. 1. It may be excited by a quarter-wave coil Y_1 or by a capacity coupling. It will be shown later in the article that for a half-wave aerial, at any wavelength, the following statements are true :—

Radiation resistance of half-wave aerial referred to current at centre of aerial = 80 ohms
Voltage above earth at ends of aerial for 1 ampere at centre of aerial ... ... = 500 approx.
∴ Current at centre of aerial for 500kW radiated ... = $\sqrt{\frac{500,000}{80}}$
= 79 amperes
∴ Voltage at ends of half-wave aerial for 500kW radiated ... ... = 79 × 500
39,500 volts R.M.S.

This latter is a voltage for which it would be quite easy to provide insulation, so that the practical limit to the radiation of energy on short waves at present is not the aerial but the transmitter.

We may contrast these figures with those for the aerial of the British Post Office Station at Rugby as given by Mr. Shaughnessy in his paper before the I.E.E.[*] From this we take the following figures :—

Effective height of aerial = 185 metres
Wavelength ... = 15,500 metres
Aerial current ... = 600 amperes
Aerial kilowatts ... = 306
Voltage on aerial ... = 180,000 volts R.M.S.

At this wavelength the radiation resistance is :—

$$1{,}580\left(\frac{185}{15{,}500}\right)^2 = \underline{.225 \text{ ohms.}}$$

Kilowatts radiated for 600 amperes in aerial $= 10^{-3} \times 600^2 \times .225 = 81$kW.

If we take 20 per cent. as a maximum value for the earth losses when using a half-wave aerial we get the following comparative figures :—

	Rugby aerial.	Half-wave aerial.
Aerial kilowatts ...	306	100
Kilowatts radiated	81	80
Aerial efficiency ...	26.5%	80%
Aerial voltage ...	180,000 R.M.S.	15,000 R.M.S.

This table proves nothing as regards the relative advantages of long and short-wave transmission, but it certainly shows in a striking manner that the difficulties on short wavelengths do not lie in the aerial system.

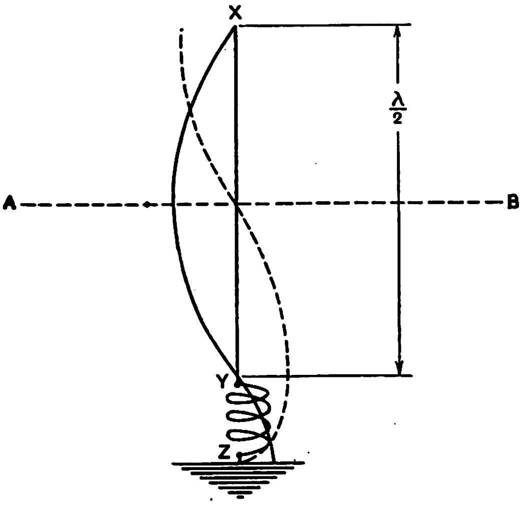


FIG. 1.

The calculation of the constants of a half-wave aerial is as follows :—

1. Radiation Resistance.

The ordinary formula for the radiation resistance of an earthed aerial is :—

$$R_a = 1{,}580\,(h/\lambda)^2 \text{ ohms}$$

where R_a = radiation resistance
h = effective height of aerial
λ = wavelength

We can cut the half-wave aerial through the centre by a conducting plane *A B* in Fig. 1 and regard it as made up of two earthed quarter-wave aerials.

Effective height h for $\frac{1}{4}\lambda$ aerial =

$$\tfrac{1}{4}\lambda \,.\, \frac{\text{Arithmetic mean value of sine curve}}{\text{Maximum value of sine curve}}$$

$$= \tfrac{1}{4}\lambda\frac{2}{\pi} = .159\lambda$$

$$\therefore \left.\begin{array}{l}\text{Radiation}\\ \text{resistance}\\ \text{of } \frac{1}{4}\lambda \text{ aerial}\end{array}\right\} = 1{,}580\left\{\frac{.159\lambda}{\lambda}\right\}^2 = 40 \text{ ohms}$$

$\therefore$ Radiation resistance of $\frac{1}{2}\lambda$ aerial referred to current at the centre = 80 ohms

2. Ratio of Maximum Voltage to Maximum Current.

To determine this we can use the fact that when the voltage amplitude is a maximum the current is zero, and *vice versa*, whilst the energy in the two cases is the same.

Let I = Maximum current at base of $\frac{1}{4}\lambda$ aerial.
V = Maximum voltage at free end.
L = Inductance in henries of $\frac{1}{4}\lambda$ wire for uniform current.
C = Capacity in farads of $\frac{1}{4}\lambda$ wire for uniform voltage.
l = Length of $\frac{1}{4}\lambda$ wire.
r = Radius of wire.

If the current were uniform the electrokinetic energy would be $\frac{1}{2}LI^2$. But since the current has a sinusoidal distribution the electrokinetic energy is $\frac{1}{2}L \times$ average value of $(I \sin \theta)^2$ between 0 and $\pi/2$.

The average value of $(\sin^2 \theta)$ for these limits is $\frac{1}{2}$.

$\therefore$ Electrokinetic energy $= \frac{1}{4}LI^2$.

A similar argument shows that the electrostatic energy $= \frac{1}{4}CV^2$.

Equating these two forms of energy we get :—

$$\tfrac{1}{4}LI^2 = \tfrac{1}{4}CV^2$$

or $$V/I = \sqrt{L/C}$$

---

[*] 14th April, 1926. For Abstract see *E.W.*, May 1926, p. 271.

To calculate the value of $\sqrt{L/C}$ we have the formulæ:—

$$L = 2l\left(\log_e \frac{2l}{r} - 1\right)10^{-9} \text{ henries}$$

$$C = \frac{l}{2\left(\log_e \frac{2l}{r} - 1\right)} \; \frac{1}{9 \times 10^{11}} \text{ farads}$$

whence

$$\sqrt{L/C} = 60\left(\log_e \frac{2l}{r} - 1\right)$$

The value of this expression does not vary rapidly with practical ratios of l/r.

Taking

$l = 10$ metres, $r = 1$ mm, $2l/r = 20{,}000$.

$$V/I = \sqrt{L/C} = 60(4.301 \times 2.303 - 1) = \underline{\underline{534}}$$

If a ratio of $l/r = 1{,}000$ had been used we should have found $\sqrt{L/C} = 400$ and we shall take 500 as a fair average value. The ratio of V/I will be approximately the same for a half-wave aerial as for a quarter-wave earthed aerial. In this calculation we have used the maximum values of V and I, but the ratio is unchanged if both are R.M.S. values.

Book Review.

WIRELESS DIRECTION-FINDING AND DIRECTIONAL RECEPTION. By R. Keen, B.Eng., A.M.I.E.E. Second and Enlarged Edition, 490 pp., with 329 illustrations. London: Iliffe and Sons Ltd., 1927. Price 21s. net.

The application of directional wireless as an aid to both aerial and marine navigation is steadily gaining in popularity, and the mariner and pilot are learning that a wireless direction-finder used under proper conditions is at least as reliable as other and older navigational instruments. In addition to this application the directional receiver is now in common use to obtain increased selectivity in wireless communication, and also as a powerful instrument in scientific research on the phenomena of the propagation of wireless waves over the earth's surface. Workers in all these branches are now adequately catered for in the volume under review. It is pleasing to find that in the second edition of his book, Mr. Keen has met practically all the criticisms levelled against the first edition. The book has been very thoroughly revised and brought up to date. A considerable enlargement has resulted from the extension of its scope to include an account of directional receiving systems of the beam, Beverage antenna and closed loop types, which are now of such vital importance in dealing with the continually extending commercial services.

In the early chapters the fundamental theory of aerial systems and the closed loop direction-finder is clearly dealt with in language which makes only the simplest demands upon the mathematical ability of the reader. The practical arrangements of the most important commercial types of rotating frame-coil direction-finder in use at the present time are described with the aid of a large number of photographs and diagrams. Later chapters deal with the Bellini-Tosi system of direction-finder and carefully prepared working details are given of the installation of this system at both ship and shore stations. Opportunity is found here also of introducing a description of the multi-way directional receiving arrangements in which eight communication channels are operated simultaneously from one pair of Bellini-Tosi loops. Direction-finding in the air, and the special problems connected therewith are treated in a separate chapter, while attention is drawn elsewhere to the merits of the directional beacon transmitter.

The operator of a wireless direction-finder soon discovers that he must become familiar with the elements of field and nautical astronomy and the use of the various types of maps and charts, but he will find his needs fully catered for in the two chapters dealing with these subjects. The chapter entitled "Night Effect and Other Freak Phenomena" has been revised in a way which shows that the author has kept thoroughly abreast of modern scientific research; and the subject is presented in a manner which gives a true perspective of the problem to the wireless operator and navigator, so enabling them to avoid possible errors which might arise in the use of the direction-finder over long ranges at night. A bibliography arranged in an excellent manner and comprising 374 references in chronological order from 1893 to 1927 forms a very valuable portion of the book, which concludes with a useful index.

Altogether the writer has had great difficulty in finding anything to criticise in a book which has been conscientiously written and produced in a manner which leaves nothing to be desired. The work can be confidently recommended as a very reliable handbook to all those interested in the science and practice of directional reception, whether as navigators, operators, engineers or experimenters.

R.L.S.-R.

Rotating-Beacon Radio Transmitters.

Papers read before the Wireless Section, Institution of Electrical Engineers, on Wednesday, 4th January, 1928.

At the meeting of the I.E.E. Wireless Section held on 4th January, three papers were read on the subject of Rotating-Beacon Radio Transmitters.

Abstracts of the three papers and of the general discussion which followed their reading are given below.

* * * *

(1) Rotating Loop Radio Transmitters and their application to Direction-finding and Navigation —by T. H. Gill and N. F. G. Hecht, M.I.E.E.

ABSTRACT.

This paper deals particularly with a method of directional transmission which has been developed by the Air Ministry at the Instrument Design Establishment, Biggin Hill, and later at the Royal Aircraft Establishment, South Farnborough. The principal object of the method is to eliminate direction-finding equipment and to reduce operational difficulties in aircraft.

The advantages of the system are: (*a*) No special receiving apparatus is required and any ordinary receiving set can be employed; (*b*) Observations are simple to make and operators do not require even to be very skilled in reading Morse; (*c*) The characteristic to be observed is usually well defined; (*d*) No quadrantal error arises and no corrections of the bearings are required; (*e*) Any number of craft can use the system simultaneously.

Methods Investigated.

In the paper brief accounts are given of some of the methods of directional transmission investigated. These first included Bellini-Tosi transmission and the "variable wavelength method," described by J. Erskine-Murray and J. Robinson,* after which the investigations were confined entirely to the single rotating-loop transmitter dealt with by the authors.

R.A.F. Rotating Loop Transmitter.

(*a*) *General Principles.*—When a loop is used as a transmitter maximum energy is radiated in the plane of the loop and minimum at right angles, giving the usual "figure of eight" polar diagram of Fig. 1. If the loop be rotated in azimuth an observer at any point on the circumference will receive a signal with two maxima and two minima in every revolution of the loop. If the loop rotates uniformly at a speed of say, one revolution per minute and a distinctive signal is sent out when the plane of the loop is North-South, the observer can obtain the time interval between the N.-S. indication and the moment of maximum or minimum signal, from which his bearing with respect to the loop is easily deduced. As usual, the minimum indication is preferable, being much more sharply defined.

It is shown in the paper that the magnetic field radiated from a coil is equal to the field from one side of the coil multiplied by the phase angle θ corresponding to the distance l between the sides of the coil in terms of the wavelength. While this is small compared with the radiation from an open aerial with the same current, it is important to note that the high-frequency resistance of a loop can be made very small, and it is therefore possible to produce much greater oscillating current in a loop than in an aerial for the same primary input power. The comparison between loop and aerial is therefore much more favourable than might appear at first sight.

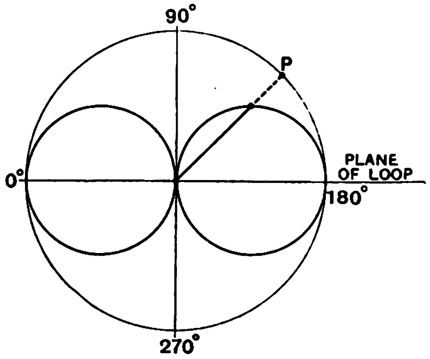


Fig. 1.

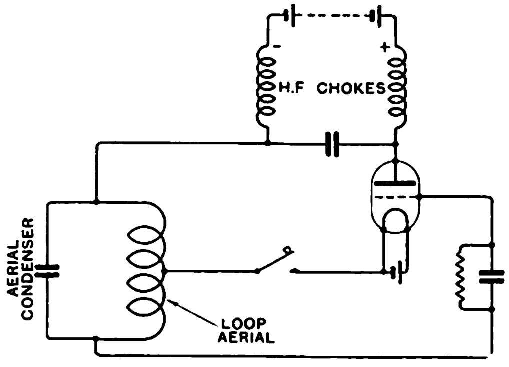


Fig. 3.

(*b*) *Development.*—An account is given of the work done in the development of the rotating loop transmitter. The first coil used was 10 ft. square with four turns spaced 6 in. apart. The bottom of the coil was 4 ft. 6 in. above ground level. The coil was tuned to 1,100 m. by a condenser, and the whole circuit energised by a standard R.A.F. transmitter to give I.C.W. signals. Very good minima were observed when the loop was rotated by hand, but on uniform rotation it was noticed that these were not of equal intensity and were not 180 degrees apart, due presumably to the well-known "antenna effect." A small change of wavelength was also discernible, especially when C.W. was used.

---

* *J.I.E.E.*, 1922, Vol. 60, p. 352.

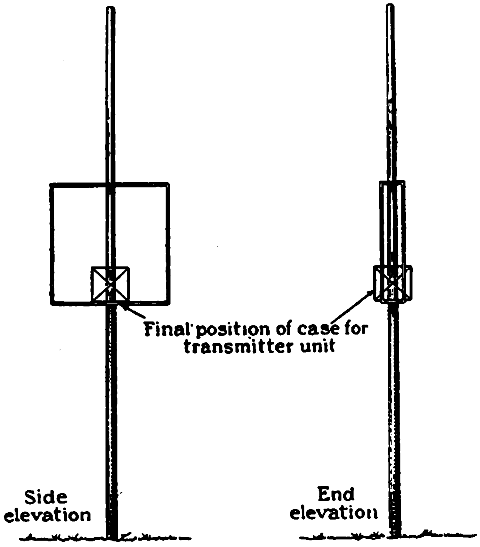


Fig. 6.

After various experiments on the height of the loop and the disposition of the apparatus, a satisfactory arrangement was produced as shown in Figs. 6 and 7,* utilising the circuit shown in Fig. 3.

The H.T. generator and the batteries for heating the valve filament were placed in the hut (on ground) and connected to the transmitter by slip rings and brushes. The leads were metal braided cable with the braiding earthed. The transmitted wavelength remained constant during the rotation of the loop, and the minima were practically equal in intensity, and very sharply defined. The keying of the circuit was automatically carried out by the rotation of the loop.

The development then proceeded mainly along the lines: (1) Removal of mechanical difficulties in housing and rotating the loop aerial; (2) Increase of range; (3) Production of perfect minima 180 degrees apart; (4) Use of I.C.W. to enable re-

---

* The authors' original figure numbers are adhered to throughout these Abstracts.

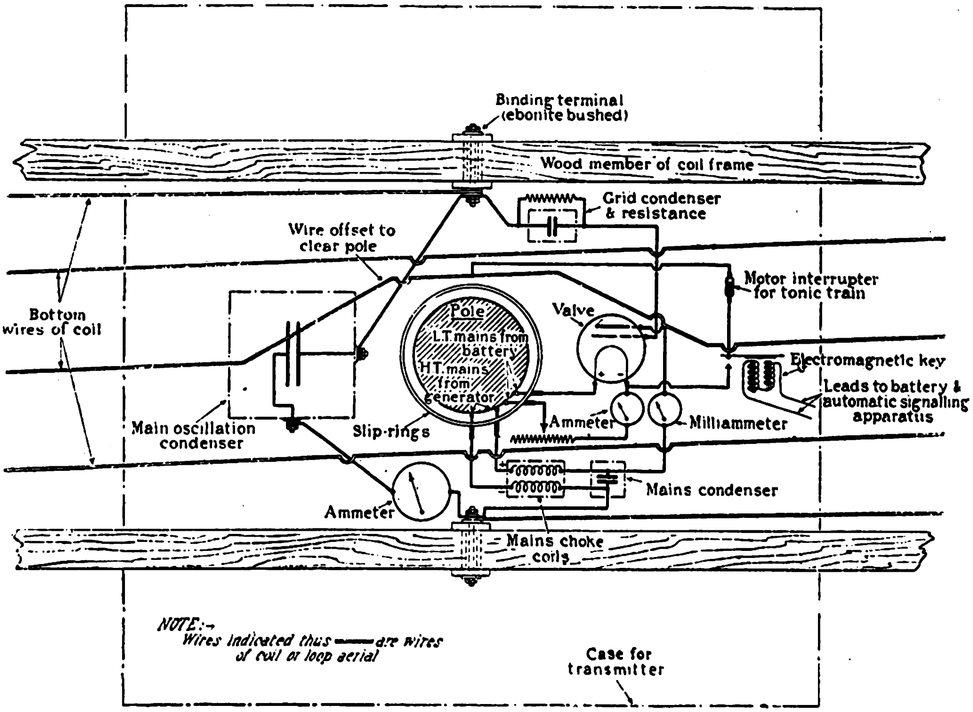

Binding terminal (ebonite bushed)
Wood member of coil frame
Grid condenser & resistance
Wire offset to clear pole
Motor interrupter for tonic train
Bottom wires of coil
Pole
L.T. mains from battery
H.T. mains from generator
Valve
Electromagnetic key
Leads to battery & automatic signalling apparatus
Main oscillation condenser
Slip-rings
Ammeter
Milliammeter
Mains condenser
Ammeter
Mains choke coils
NOTE:- Wires indicated thus —— are wires of coil or loop aerial
Case for transmitter

Fig. 7. *Directional transmission from a loop aerial. General arrangement of transmitter (schematic). Part plan of lower portion of coil and transmitter.*

ception to be effected on simple spark receiving sets such as are used on ships.

The housing and protection of a loop of the size hitherto used was very difficult. A smaller loop was therefore decided upon, with a reduction of wavelength (to 525 metres) to compensate for the loss of range consequent on reduction of coil. The new coil was of six turns on a frame 5 ft. square, tuned by a condenser of $0.00088\mu F$. The condenser consisted of nineteen aluminium plates, each 36 in. by 18 in. and spaced 2½ in. apart with spacing pieces of American white wood. More recently the wavelength of the Farnborough Beacon has been changed from 525 to 707 metres, chiefly on account of the interference from other stations. The size of the frame remained unaltered, but additional strands were added to the turns of the loop, which now consists of 1,458/40 S.W.G. black enamelled wire. The aerial condenser is made up of thirteen plates each 4 ft. 9 in. by 2 ft. 6 in., spaced 2 11/16 in. apart, giving a capacity of approximately $0.00166\ \mu F$. The loop current is 72 amperes and the H.T. input is about 2,500 watts (250 milliamperes at 10,000 volts). The H.T. supply is from an A.C. generator, stepped up and rectified by two valves giving full wave rectification. Batteries for heating the oscillating and rectifying valve filaments were dispensed with and step down transformers used on the A.C. supply.

Although the minima obtained were then 180 degrees apart, it was found that they were of unequal intensity. This was found to be due to the condenser plates—now of dimensions comparable to those of the coil—having their planes parallel to that of the loop. Refixing them with their planes at right angles to that of the loop gave minima more nearly equal in intensity. They are still slightly different, but bearings can be taken from either with the same degree of accuracy.

Some of the asymmetrical effects are possibly due to local conditions, as differences are noticeable between the performance of the 525 metre beacon at Farnborough and that at Gosport, although the two are identical except for the sites which differ considerably.

(*c*) *Timing Signals*.—In the first experiments the indication of the North-South position was given when the frame was oriented North-South and giving maximum radiation in this plane. It is now arranged that the North-South indication shall be transmitted when the radiation in this direction is a minimum. The method of signalling is shown in Fig. 9. The letter " V " is sent as a warning that the North point is approaching, followed by two timing dots which, with the commencement of the continuous signal, can be counted as three. The observer counts " one," " two," " three " in time with the signals and releases the stop watch or chronograph on " three." The letter " B " is used as a warning for the East point. The East signal is necessary to overcome the difficulty of receiving the North indication when the craft is North or South of the beacon, as on that bearing signal strength is a minimum, and it is then more satisfactory to obtain a timing signal corresponding to a minimum radiation in an East-West direction. The beacon is calibrated on time North.

(*d*) *Best Speed*.—It has been found that a speed of one r.p.m. is probably the best for this type of beacon in addition to which it is the same as that of the second's pointer of watches. Actually a speed of one revolution for 72 seconds gave most consistent results, but there was so little difference between that and 60 seconds that it was decided to adopt the latter, rather than introduce special time pieces.

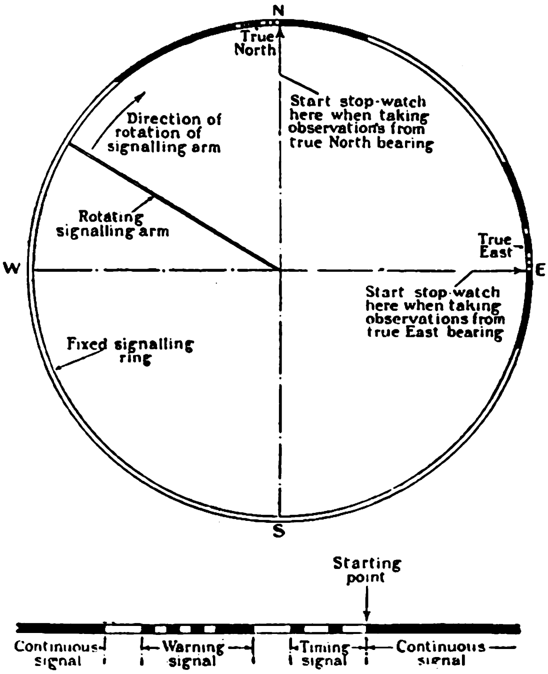

N
True North
Start stop-watch here when taking observations from true North bearing
Direction of rotation of signalling arm
Rotating signalling arm
W
E
True East
Start stop-watch here when taking observations from true East bearing
Fixed signalling ring
S
Starting point
Continuous signal
Warning signal
Timing signal
Continuous signal

Fig. 9.

(*e*) *Speed Control*.—It is essential that the loop should rotate at a constant speed, uniform throughout each revolution. Up to the present a suitable method has not been put into use for performing this without manual assistance. The problem of speed control is being investigated and two methods are about to be tried.

(*f*) *Use of Beacon in Navigation*.—Apart from its use for position finding by two or more beacons, the rotating loop appears to have a particular use in point-to-point work, which in many cases can be conducted on a single beacon. Examples are shown in Fig. 10. If an aeroplane be required to fly from *A* (beacon station) to *B*, Fig. 10 (*a*), if the bearing of *B* be, say, 300 degrees and the beacon be rotating at six degrees per second, the signal for stating the chronograph will be sent out when the N.-S. radiation is a minimum. If the navigator maintains a correct course he will hear the minimum signal at 50 seconds on the chronograph or on 300 degrees, if the dial is calibrated in degrees, with reciprocal minimum at 20 seconds or 120 degrees. Listening to the beacon and observing time of minimum he can fly from point to point using the beacon as his sole aid to navigation. In the case of flying from *C* to *B*, Fig. 10(*b*), he can first steer North until he arrives at a point where the observation of the beacon will occur at the correct time, when he must alter his course and proceed in the manner indicated above. Flights of this nature have been carried out up to a distance of 160 miles, with entirely successful results. In Fig. 10(*c*), if terminal air posts are at *A* and *B* respectively and each has a beacon, the traffic lines could be arranged as indicated, navigation being performed as in the second example quoted.

(*g*) *Night Effect in Air.*—Although it would be premature to say that this method is free from night variations, up to the present no variations of direction have been noticed, although on many occasions the observer has particularly looked out for them.

Appendix.

A lengthy appendix gives various tables of results from ground tests and air tests.

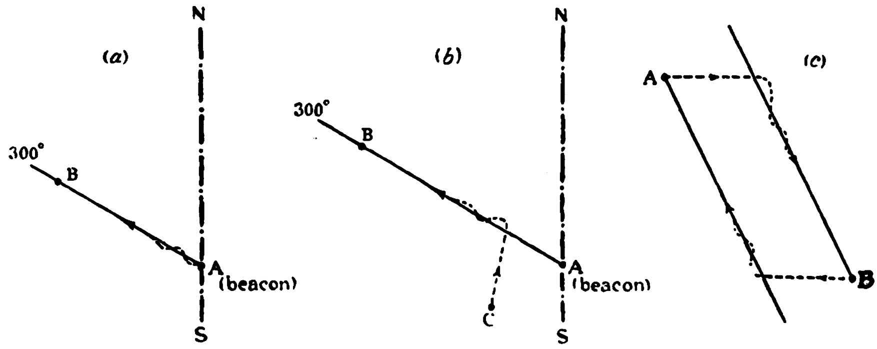


Fig. 10.

The following extracts taken from reports give typical examples of results obtained during recent extensive tests carried out in aircraft in May and June 1927.

Accuracy of Bearings.—A total of 558 bearings were taken, resulting as follows :—

Accuracy	OK	±1	±2	±3	±4	±5
No. of bearings..	65	104	97	87	64	40

Accuracy	±6	±7	±8	±9	±10	±11
No. of bearings..	26	30	21	6	6	5

Accuracy	±12	±13	±14	±15
No. of bearings..	1	3	2	1

It should be borne in mind, however, when considering the above table that it includes *all* bearings taken and thus includes errors due to inexperienced operators, minor faults in beacon itself, inaccurate timing due to wireless telegraph interference, etc. In view of this, the following block of bearings are given as taken by a fairly experienced operator when the beacon was known to be correct in itself and when wireless interference was at a minimum.

Number of bearings taken = 95.

Accuracy	OK	±1	±2	±3	±4	±5
No. of bearings..	12	27	18	9	10	6

Accuracy	±6	±7	±8	±9	±10
No. of bearings..	5	4	2	1	1

From the trials it seems that errors in bearings are due to the following causes :—

(*a*) Faulty stop watch.
(*b*) Beacon erratic in time of rotation.
(*c*) Apparent errors due to faulty pin pointing.
(*d*) Errors due to wrong setting of beacon.
(*e*) Errors caused by wide minima due to weak signals or strong interference.
(*f*) Errors caused by lack of practice.
(*g*) Errors due to incorrect timing between second pilot and operator.

All of these faults have occurred during the test trials carried out, and some allowance for these errors should be made when judging the reports. It is probable that the bearings obtained were better than they appear in the various reports.

* * * *

Some Experiments on the Application of the Rotating-Beacon Transmitter to Marine Navigation. — by R. L. Smith-Rose, D.Sc., Ph.D., A.M.I.E.E., and S. R. Chapman, M.Sc., A.M.I.E.E.

ABSTRACT.

The rotating-beacon transmitter was exactly similar to that described by Messrs. Gill & Hecht in the previous paper. It was set up by the Air Ministry at Fort Monckton near Gosport in July, 1926, and loaned to the Radio Research Board for the purpose of conducting the experiments described in the present paper. The beacon was operated throughout on its normal wavelength of 525 metres.

The site being chosen more for convenience than for its wireless virtues, and detailed calibration of the beacon was carried out by taking bearings from fixed points in various directions. When the path of transmission is partly or entirely overland, the observed bearings are subject to a small permenent error, evidently associated with a coastal deviation effect similar to that experienced in ordinary direction finding. When the bearings were made in the small open sea sector or in the open sea beyond the Isle of Wight, the permanent error was limited to one degree or two degrees.

Experiments carried out at Sea.

With the assistance of the Southern Railway Co. and of H.M. Signal School, experiments were carried out at sea on the routes shown in Fig. 2.

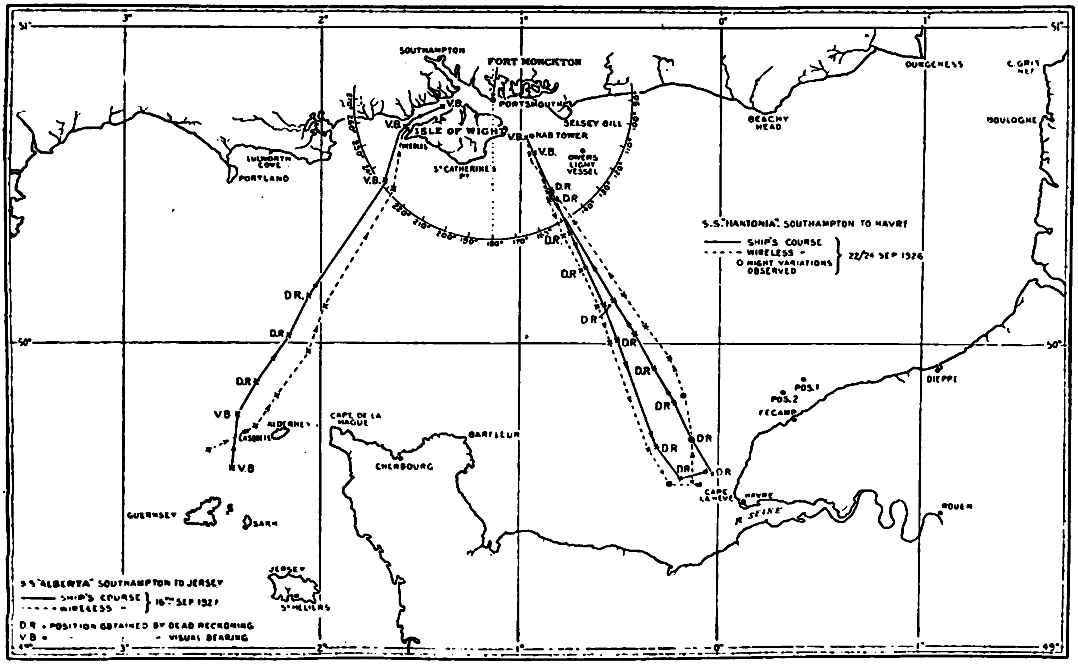


Fig. 2. *Chart showing portion of the English Channel utilised in the tests of the radio beacon with ships. Typical courses are shown for the trips between Southampton and Havre and Southampton and Guernsey, also the sites of the fixed-position tests are shown at Owers Light Vessel, Fécamp* (1 *and* 2), *Havre and Jersey* (*St. Heliers*).

(*a*) *Between Southampton and Havre.*—Path entirely oversea, and of almost constant bearing. Differences between wireless bearing and that obtained from ship's position by dead reckoning up to nine degrees, but majority agreed to within two degrees. Wireless bearing possibly more accurate, and larger differences possibly due to incorrect estimation of ship's position. Night effect observed in the form of blurred minima and tendency of successive bearings to wander erratically.

(*b*) *Between Portsmouth, Fécamp and Owers Light Vessel.*—Also in open sea path; trips in daylight but poor visibility. Maximum difference between observed and estimated bearings up to five degrees.

(*c*) *Between Southampton and Channel Islands.*—Isle of Wight intervenes in wireless path. Outward journey by day and return by night. Differences ranging up to 12 degrees, and night errors experienced at distances exceeding 50 miles.

The experience gained on these and other sea trips suggested that bearings observed on the beacon have an accuracy somewhat superior to that obtained from an estimate of the ship's position, except when the ship was in calm weather and it was possible to make a fairly accurate visual fix. Further experiments on night error are described in the next section.

Tests Carried Out at Fixed Positions on Sea and Land.

A continuous series of observations was made on the beacon from various positions, each test lasting for 12 hours or more. The positions were selected so as to provide a variety of ranges and also to show the difference between transmission over sea and land.

The results were analysed and the authors drew the following conclusions: (i) The maximum error by day at distances up to 56 miles overland or 92 miles oversea is 6 degrees. Up to 23 miles over 85 per cent. of all observed bearings are correct to 2 degrees. (ii) At night the above accuracies hold for distances of 14 miles overland and 23 miles oversea.

(iii) At 92 miles oversea night errors up to 18 degrees may be encountered, but over 84 per cent. of the observed bearings are correct within 5 degrees.

(iv) At 55 miles overland the errors are much more serious at night and may range up to 32 degrees.

(v) The mean bearing of any position is practically the same for day and night. The effects of (iii) and (iv) may be largely compensated for by taking the mean of a number of successive bearings.

(vi) As far as concerns the distances at which night errors are encountered there is practically no difference between C.W. and I.C.W. transmissions.

Comparison of Bearing Observations by Beacon and by Direction-finding.

(*a*) *Day Tests at Various Positions.*—Tests were made at different positions on land by a simple receiver for reception of signals from the rotating beacon and a single coil direction finder taking D.F. bearings on the beacon, while this was of fixed orientation, maximum for the receiver. The aerial and D.F. coil were at sufficient distance to avoid mutual interference, while the former was additionally disconnected during observations by the latter. The results were summarised in tabular form. The error of the mean bearing observed on the D.F. set is generally different from that observed on the rotating beacon, but the range of errors on the two systems is of about the same order. These errors are considered to be due to deviations of the waves at the boundaries between sea and land, and it is suggested that the beacon provides a useful means of investigating this phenomenon since it can be used as a "null" method for transmission in the desired direction.

(*b*) *Day and Night Errors Compared.*—Tests were carried out to study the variations observed with the two systems over period of from one hour upwards. One set of tests was made at Slough using a single coil direction finder and another receiver on a vertical aerial. Another set was done at Jersey Quay on board a Southern Railway Co.'s ship, using the ship's D.F. set and the ordinary aerial respectively. Results were shown in tabulated form. Variations range from 20 degrees to 57 degrees in the case of the beacon and from 69 degrees to 130 degrees in the case of D.F. bearings, but even under these conditions over 86 degrees of the beacon bearings and over 62 of the D.F. bearings are within 10 per cent. It is therefore concluded that both systems of obtaining wireless bearings are subject to night errors of the same serious order, but the effect may be mitigated by taking the mean of a number of successive bearings.

(*c*) *Comparison Tests at Sea.*—Some of the test-runs between Southampton and Jersey were done on ships fitted with D.F. which enabled similar comparisons to be made under sea-going conditions. Maximum differences between estimated and observed bearings on the beacon are shown up to 19 degrees in daylight, and between estimated and D.F. bearings up to 14 degrees in daylight. These errors are large for daylight working and are considered as being due probably to inaccurate estimation of the ship's position, as the weather was very bad.

In conclusion the authors make a comparison between the bearings observed on the rotating beacon and those obtainable with a direction-finder used in the ordinary manner. When used in fixed positions on land the direction-finder gives a somewhat superior accuracy, as it is not easy to obtain bearings on the rotating beacon to an accuracy of less than 2 degrees, whereas a good land direction-finding station should give bearings reliable to 1 degree. As is well known, however, the land direction-finding station is subject to errors due to local conditions which necessitate its frequent calibration, but the observed bearings from the rotating beacon have been shown to be largely immune from conditions local to the receiver. When the wireless bearings are taken on board a ship at sea, however, the case is somewhat different. The direction-finding bearing is taken relative to the direction of the ship's head, and its accuracy depends upon the steadiness of the ship and also upon the accuracy with which the ship's head is given by the compass reading at any desired instant. The bearing obtained by the rotating beacon is entirely free from this limitation and its accuracy is practically the same whether the ship is at sea, in motion or at anchor, or in dock. Furthermore, no correction or compensation corresponding to the quadrantal error associated with the ship direction-finder is necessary. The limitation of range of accurate bearings due to night effect has been shown, both theoretically and experimentally, to affect both systems to the same degree.

* * * *

(3) A Theoretical Discussion of Various Possible Aerial Arrangements for Rotating-Beacon Transmitters—by R. L. Smith-Rose, D.Sc., Ph.D., A.M.I.E.E.

This paper discusses three aerial arrangements for a rotating-beacon transmitter from the theoretical point of view. The three systems are the single coil, the double spaced coil, and the Adcock aerial arrangement.

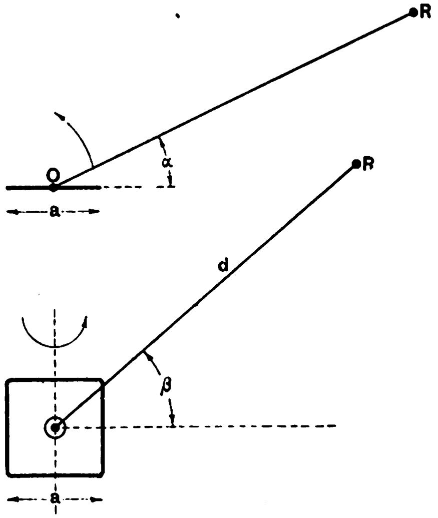


Fig. 1. *Single-frame coil transmitter at* O. *Receiver at R, distance d, orientation* α, *and elevation* β.

(1) Single Rotating Coil Transmitter.

(*a*) *General Equation for Radiation.*—The conditions are shown in Fig. 1, and the general expression for the magnetic field radiated is

$$H_1 = \frac{H}{d}\sqrt{[(\cos^2 \alpha + \sin^2 \alpha \sin^2\beta)]} \quad .. \quad (1)$$

Along the ground where $\beta = 0$ this reduces to the ordinary cosine law

$$H_{1(\beta=0)} = \frac{H}{d} \cos \alpha \quad .. \quad .. \quad (2)$$

and the field passes through zero when the plane of the coil is perpendicular to the direction OR.

When, however β is not zero the radiated field is never zero, whence it is shown that signal minima only and not a zero of intensity will be observed when the plane of the coil is perpendicular to OR. This indicates that absolute zeros are unobtainable in the air when receiving from a beacon on the ground.

(*b*) *Reception of Direct and Indirect Waves from Rotating Coil Transmitter.*—The conditions are shown in Fig. 2, and the general expression for the total effective field acting on a vertical aerial at R is given as

$$H_R = H_1 + (H_2 + H_3) \cos \beta$$

$$H_R = \frac{K_1 H_m}{2l} \cos \omega t \cos \alpha + \frac{K_2 H_m}{2\sqrt{(l^2 + h^2)}} (1 + \rho_v) \cos \beta \cos (\omega t + \phi_1) (\cos^2 \alpha + \sin^2 \alpha \sin^2 \beta)^{\frac{1}{2}} \quad .. \quad (5)$$

where K_1 is a factor for ground attenuation, K_2 for attenuation at the deflecting layer and ρ_v is the coefficient of reflection of the ground. In daytime when $K_2 = 0$, this reduces to the form of (2) and single values are obtainable, *i.e.*, correct bearings are observed. At night, however K_2 will not in general be zero, so that when the coil is at right angles to OR the received signal intensity is not zero and is not necessarily passing through a minimum.

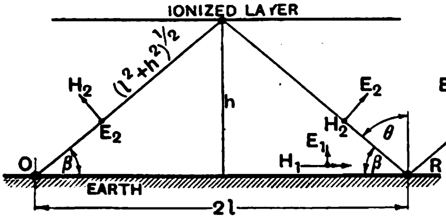


Fig. 2. *Reception at R of direct and indirect waves from coil transmitter at* o.

This case is then examined by making a comparison of night error due to down coming waves with a rotating beacon and with an ordinary direction-finder, employing figures and constants which the author's previous work have proved to be applicable in the latter case.

It is shown that under similar conditions and for transmission overland or sea, observations made with the rotating beacon are liable to errors of the same order as those experienced in the use of a closed coil direction-finder.

(2) Double Rotating-coil Transmitter.

The arrangement suggested is after the manner of the directional receiving system described by H. T. Friis,* employing two co-planar coils operating differentially as in Fig. 3.

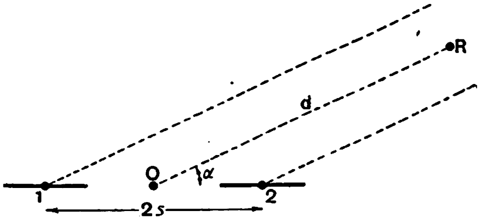


Fig. 3. *Transmitter formed of two co-planar coils about a central vertical axis at* o. *Receiver at R, distance d, orientation α, and elevation β.*

(*a*) *General Equations for Radiation.*—The expression for the field intensity is now of the form

$$H_{R(\beta=0)} = \frac{KH_m}{d} \cos \alpha \{\sin (\omega t - \chi) - \sin (\omega t + \chi)\}$$

$$= \frac{KH_m}{d} \cos \alpha \cdot 2 \cos \omega t \sin \chi \quad .. \quad (7)$$

From analysis of this the author concludes that the signal minimum with the double coil system will not be so sharp as with the single coil.

On the other hand if the receiver is raised so as to subtend an angle of elevation β at o the field is of the form

$$H_R = \frac{KH_m}{d} 2 \cos \omega t \sin \chi (\cos^2 \alpha + \sin^2 \alpha \sin^2 \beta)^{\frac{1}{2}} \quad (8)$$

and the author shows that true signal zeros will be observed when receiving in the air from such a system in daytime.

(*b*) *Reception of Direct and Indirect Waves.*—Treated in the same manner as in section 1 (*b*), the expression for the total effective field is given as

$$H_R = \frac{K_1 H_m}{2l} \cos \alpha \, 2 \cos \omega t \sin \chi + \frac{K_2 H_m}{2\sqrt{(l^2+h^2)}} (1 + \rho_v) \cos \beta . 2 \cos (\omega t + \phi_1) . \sin \chi . (\cos^2 \alpha + \sin^2 \alpha \sin^2 \beta)^{\frac{1}{2}} . \quad (9)$$

From this it is shown that, while the time of occurrence of minimum giving the correct observed bearing remains unaltered during all conditions of night effect and down coming waves, other secondary minima may be obtained, the observed bearings on which may be in error by the same amounts as those obtained with a single-coil transmitter.

(3) The Adcock Aerial System as a Transmitter.

The use in reception of the aerial system due to F. Adcock has already been described by the present author and R. H. Barfield,† where it is shown to provide a valuable means for eliminating night errors in direction finding. The system may be regarded as a pair of spaced vertical aerials with the currents flowing in opposite phase, as in Fig. 4.

---

* *Proc. I.R.E.*, 1925, Vol. 13, p. 685.

† *J.I.E.E.*, 1926, Vol. 64, p. 831, abstract in *E.W. & W.E.*, June, 1926.

(*a*) *General Equation for Radiation.*—This is shown to be of the form

$$H_R = \frac{KH}{d} \cos \beta \,.\, 2 \cos \omega t \sin \chi \quad .. \qquad .. \ (10)$$

From this it is shown that there is no radiation in the plane perpendicular to the plane of the two aerials, this being true for all values of β.

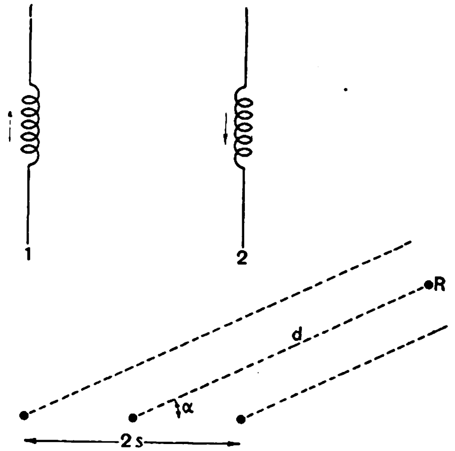


Fig. 4. *Arrangements of pair of vertical aerials as a transmitter on the Adcock system.*

(*b*) *Reception of Direct and Indirect Waves from the Adcock Transmitter.*—The expression for the resultant field is now of the form

$$H_R \doteq \frac{K_1 H_m}{2l} 2 \cos \omega t \sin \chi \dot{+} \frac{K_2 H_m}{2\sqrt{(l^2+h^2)}} (1+\rho_v) \cos^2\beta$$
$$2 \cos (\omega t + \phi_1) \sin \chi \quad .. \qquad (11)$$

and it is shown that the condition for the direct and indirect waves to interfere is independent of α and therefore of the rotation of the transmitter. It is, in fact, simply the condition which produces fading as ordinarily observed on wireless transmitters.

It is therefore concluded that with such a transmitter the signal intensity at the receiver will pass through the zero whenever the plane containing the aerials is perpendicular to the direction of the receiver. This is the only zero to be observed under any conditions of downcoming waves, and bearings will remain correct throughout all conditions of night effect in transmission.

DISCUSSION.

A general discussion on the subject of rotating beacon transmitters followed the reading of the papers.

The discussion was opened by **Capt. Kennedy-Purvis, R.N.,** who spoke as one concerned with using the device at sea. The use of directional wireless in navigation was very important and navigators must have confidence in the system employed. Bearings taken by shore direction-finding stations were more accurate than those taken afloat. A definite fix could only be made by the co-operation of two shore D.F. stations or by a ship taking bearings on two shore stations. The beacon method necessitated nothing but the ordinary wireless gear of the ship and represented a great advance. He hoped the authorities concerned would press the rotating beacon which he regarded as being especially useful to the captain of the small ship.

Mr. Davie said that although the rotating beacon was at first sight very attractive, it could only remain so if it proved economical and efficient. The economic aspect was the final arbiter. He then dealt with the difficulty of supplying calibration charts of each such beacon station to all the ships that might use it and of the possible need for re-calibration. Were causes of error in the calibration of the beacon due to site? Having regard to the results, he thought there were two conditions to be fulfilled, (1) An ideal and symmetrical site, (2) a homogeneous path round the whole of the arc of operation. These have considerable bearing on the economic aspect. The ideal site would be a ship out on the water; the next best a small island such as Lundy or one of the Scillies. On the mainland he could think of few places except perhaps Dungeness and Portland Bill which might be suitable. For the ideal station the capital cost and maintenance charges would be high for the number of beacons required as compared with the use of D.F. on ships receiving the ordinary coastal transmissions.

Dr. J. Robinson did not agree with this pessimistic view of the results. The people who had developed the beacon were to be congratulated on its success. The rotating beacon was first intended for aircraft. There was no trace of night error in working with aircraft and no trace of effects due to site, but the matter of night error must be investigated by the Air Ministry. He agreed with Capt. Kennedy Purvis as regards its valuable aid to marine navigation. The results quoted by Dr. Smith-Rose were very good, especially over sea. Aircraft, however, remained the most important need, and he hoped the Air Ministry would have confidence to build a bigger beacon station with a greater range up to 500 or 600 miles. As regards improvement of the beacon transmitter he agreed that the Adcock aerial was no doubt ideal. The present type of beacon transmission was undoubtedly the best available, compared with the American system or with the short wave beam. The latter he did not consider fit for application to navigation.

Dr. S. H. Long first dealt with the similarity of the problem in transmission and reception. In reception he had already found the single coil direction-finder best. The use of this form of D.F. reception was important on the British coast where the carrier waves of B.B.C. stations could be used as a fixed beacon transmission. Would it be practicable with the rotating beacon to utilise a vertical aerial in conjunction with the frame and work on a heart-shaped polar curve of radiation? With reference to the matter of site, he quoted a case of a D.F. set where errors were observed when it was near the edge of a hill and were removed on transferring the set much further back from the edge. He did not agree that the rotating beacon was equally useful to ships as it was to aircraft. The use of D.F. at sea was important in the prevention of collision. A considerable number of beacon stations would be necessary and the cost would be prohibitive.

Mr. R. H. Barfield was glad to see the dual sides of development and testing for results presented by the personnel responsible for the different work. In the development he thought that the fitting of all the apparatus inside the loop was a critical step in the improvement of antenna effect. The second paper gave very good information on the performance of the rotating beacon, and the authors had, from his personal knowledge, worked very hard in the accumulation of the data given in the results.

Capt. P. P. Eckersley asked whether the system had any great advantage as compared with that of ships obtaining bearings from two land D.F. stations. The ether was very full and it was undesirable to add any other steady transmissions. Working to coast D.F. stations would not be heavy in clear weather, and he favoured this even if it led to a congestion at these stations in foggy weather. Was the system described in practical use or was it merely in the state of test? What happens with the Inch Keith short wave system? There was much more room for the ether on shorter waves.

Mr. R. A. Wilmotte said that more figures on the range of the loop would be interesting. The fact shown in the third paper that generally the beacon transmitter was subject to the same effects as ordinary D.F. was in accordance with Sommerfeld's reciprocal theorem. Hence arose the advantage of the Adcock system. From consideration of various arrangements of spaced coils, he did not consider that any such arrangement could possibly give the same effect as the Adcock aerial.

Mr. Boyd said that the question was largely a matter of money. There were always ships with no D.F. fitted, and he hoped that the development of the rotating loop would not hinder the development of ship direction-finding. With reference to Capt. Eckersley's remarks as to shore D.F. stations, these were expensive, costing about £6,000 to instal and £4,000 a year to run. He sought for information as to the power necessary to work the beacon, especially as regards the change of power necessary to get equal range on other wavelengths.

Dr. Smith-Rose (participating in the discussion) said that improvement in the uniformity of speed of the Gosport beacon had been effected by the use of a tuning fork and phonic motor. The order of steadiness was now such that there was less than 1 sec. error in three hours' continuous running.

The authors briefly replied to certain of the points raised in the discussion, leaving more extended replies to be communicated.

Mr. Gill considered that the few rotating beacons necessary would be more economical than coast D.F. stations. The matter of site was under investigation. Night tests in the air had shown no great errors as were revealed on the ground.

Dr. R. L. Smith-Rose thought that errors must exist in the air and that Sommerfeld's reciprocal theorem was equally applicable here. He showed a slide illustrating the position of an aircraft relative to the ground and to the deflecting layer, when the machine was at some distance from the transmitter. It was clear that the machine was effectively under the same conditions as those at the surface of the earth. He also showed a slide illustrating the arrangement of stop watch dials to read directly in degrees when started from either the N. or from the E. reference transmission.

On the motion of the Chairman (Lt.-Col. A. G. Lee) the authors were cordially thanked for their papers.

The Physical Society's Exhibition.

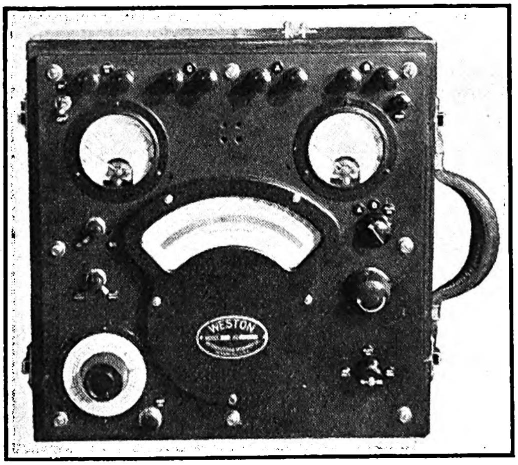
Matters of Wireless and Laboratory Interest.

THE Eighteenth Annual Exhibition of the Physical Society and the Optical Society was held this year at the Imperial College of Science and Technology, S. Kensington, on 10th, 11th and 12th January. Following the arrangement adopted last year, admission on the first two days was by ticket only, while on the third day the Exhibition was freely open to the public. An additional session was held from 10 a.m. to 1 p.m. on 11th January, admission to which was available only to Fellows of the Societies on a special ticket.

As has been the case in recent years, the Exhibition was again characterised by the large number of exhibits of great interest to the wireless worker, as well as to the laboratory experimenter in wireless or in the many branches of physics which now border so closely on wireless practice.

ELECTRICAL MEASURING INSTRUMENTS.

Electrical measuring instruments, *e.g.*, Ammeters, Voltmeters, Milliammeters, etc., were, as usual, well represented, the exhibits showing the improvements in detail which are steadily proceeding.



Valve characteristic recorder, manufactured by Weston Electrical Instrument Company. A.C. resistance magnification factor and mutual conductance are shown as dial readings.

Crompton, Parkinson, Ltd. (Chelmsford and Guiseley) exhibited a range of A.C. and D.C. instruments, including the popular "All Test," D.C. Portable Multi-range Testing Set, and the "A.C. Test" in the form of a portable A.C. multi-range ammeter and voltmeter.

Elliott Bros. (London), Ltd., showed a new current transformer for provision of a large number of A.C. ranges, their Multiversal Testing Set, and a pleasing portable moving coil galvanometer. Another interesting feature was a range of thermocouples in which the heater is insulated from the couple itself.

Everett Edgcombe & Co., Ltd., had on view the Warren Synchronous Motor, a very serviceable little machine with a wide range of uses, precision moving-iron ammeters and voltmeters, with a nickel-iron current transformer for various single and multi-ranges. Instruments for use at radio frequencies included patterns of the thermo-expansion and thermo-couple types, while for recording, graphic instruments of the "Inkwell" pattern and of the "Relay" pattern were on view, capable of recording with a maximum scale of 150μA.

The exhibits of **Evershed & Vignoles, Ltd.**, included the well-known lines of this firm, more especially in connection with resistance testing instruments of the Megger, Meg and Ducter class.

The Foster Instrument Co. showed high precision milliammeters and millivoltmeters in portable forms with the "Resilia" system of spring mounting, giving a combination of high sensitivity and ruggedness in use.

Nalder Bros. & Thompson, Ltd., exhibited an extensive range of instruments, including induction type instruments of nearly circular scale.

Circular scale instruments were also a feature at the stand of the **Record Electrical Co., Ltd.**, including a model especially suitable for laboratory or lecture demonstrations.

The Stonebridge Electrical Co., Ltd., had on view an electrostatic voltmeter up to 15,000 v., standard laboratory instruments, portable multi-range precision instruments and miniature recording instruments for various purposes.

An interesting instrument of **Messrs. Ernest Turner** (High Wycombe) was an A.C. voltmeter employing the copper oxide rectifier described in our last issue. This is used in conjunction with a D.C. movement to give an A.C. voltmeter with three scales of 1, 10 and 100 v. of practically linear openness.

The Weston Electrical Instrument Co., Ltd., had an extensive display of laboratory instruments of high accuracy and standard portable testing instruments, miniature precision meters and numerous instruments of radio application, including thermo-ammeters and galvanometers and small 2-inch panel instruments. Two-valve testing sets were also on view, one for complete test of the valve in the laboratory and the other for test of receiving sets in actual working conditions.

LABORATORY EQUIPMENT.

Laboratory apparatus of the high standard associated with the Exhibition was also well represented, and many high-grade instruments of the radio laboratory were to be seen.

At the stand of the CAMBRIDGE INSTRUMENT Co., LTD., an interesting feature was a Duddell Oscillograph of simple projection pattern, well adapted for lecture demonstration or for any non-recording purpose. A high voltage Oscillograph was also shown, capable of use up to 75,000 v. Another interesting instrument was a Schering bridge for power factor and permittivity measurement, while the Capacitance Bridge and the Mutual Inductometer, due to Mr. A. Campbell, were also attractive instruments to the wireless worker.

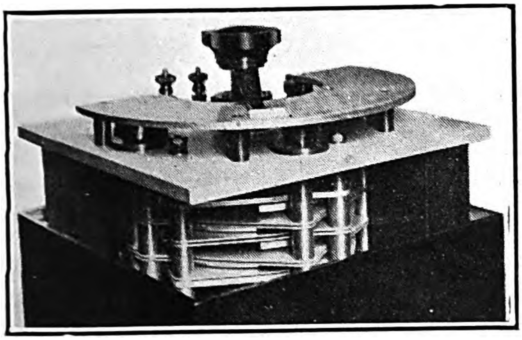
GAMBRELL BROS., LTD., were showing a new pattern laboratory condenser and a mirror galvanometer with interchangeable coils for different sensitivities. Of more purely wireless interest were this firm's range of mains receivers using A.C. or D.C. mains for all supplies.

J. J. GRIFFIN & BAIRD & TATLOCK, LTD., displayed a moving coil galvanometer with self-contained lamp and scale, and also with interchangeable suspensions, while an Ayrton Mather pattern of reflecting instrument also included this feature.

W. G. PYE & Co. (of Cambridge) showed a large range of laboratory apparatus, including electrically maintained forks, resistance boxes, galvanometers, etc.

THE SILVERTOWN COMPANY, while showing chiefly matters of line telegraph interest, had several features of wireless interest in the way of transformers, telephones, loud-speakers, etc.

H. W. SULLIVAN & Co., LTD., had on view a very extensive range of laboratory apparatus, largely of wireless interest. This included their Standard Multivibrator Wavemeter (due to Dr. D. W. Dye), variable air condensers of great precision and fixed value air condensers. Amongst condensers the new "Sullivan-Griffiths" precision variable air condenser (described in our last and present issues) was on view for the first time, and a demonstration was given of its constancy of capacity on varying the distance between the fixed and moving plates. Other interesting apparatus included various oscillating wavemeters (one for 10 to 100 metres), oscillators for audio frequencies, non-reactive bridges and ratios, and a Schering bridge for power factor and S.I.C. measurements.



The Sullivan-Griffiths Precision condenser, for use in accurate wavemeters. Adjacent dielectric gaps are electrically in series instead of parallel, and are also complementary.

H. TINSLEY & Co. showed a non-generating wavemeter to the design of Dr. D. W. Dye, a standard condenser, portable galvanometers of the self-contained mirror type for A.C. and D.C., variable inductometers, non-reactive bridges, ratios, resistance boxes, etc.

WIRELESS ACCESSORIES, PARTS, SETS, ETC.

Several of the stands were devoted to articles of purely wireless interest.

At the stand of the MULLARD RADIO VALVE Co. and MULLARD WIRELESS SERVICE, LTD., were a wide range of P.M. valves and valves of the transmitter class in the power amplifier, modulator and rectifier forms. This firm's assembly of the screened grid valve was also on view for the first time, this valve fitting into a standard valve holder, where the anode point R becomes the lead to the screen, while the actual anode is lead to a separate terminal on the top of the valve. An amplification factor of 200 is quoted. Another feature of great interest also displayed for the first time, was a Pentode or five electrode valve, this having a still extra grid (placed between the screen and the anode and joined internally to the filament). In the case of this valve the ordinary anode pin is used as anode while the screen is led to a terminal in the side of the valve cap. This valve is claimed to have an amplification factor of 60 to 100 and to give exceptionally good output with smaller grid bias than the usual type of small power-valve. Other well-known Mullard accessories, resistances, grid leaks, loud-speaker, etc., were also on view.

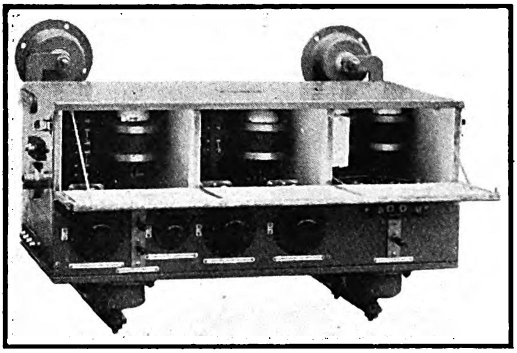
THE MARCONI-OSRAM VALVE Co., LTD., had on show a very complete display of valves of all sizes and for all purposes, including the now well-known screened valve of this firm, and a selection of short-wave valves for transmitting and receiving, certain of these being of the patterns in use at the Beam Stations.

Marconi valves were also on display at the stand of the MARCONIPHONE Co., LTD., along with a wide range of receivers. Two of these included the screened valve, one set being in the form of a constructional receiver, while the other had three H.F. stages with these valves. Other interesting receivers included an eight-valve supersonic with single control. The Marconiphone pattern of Rice-Kellogg loud-speaker was also on view, and two new reed-driven cones.

At the MARCONI WIRELESS Co.'s stand were shown a short-wave receiver and a Marconi press receiver for "all-world" use, while a time signal portable receiver for the use of surveying parties was also on view.

The RADIO COMMUNICATION Co. had a single exhibit in the form of their automatic call device, which was shown in operation, responding to three dashes each of four seconds.

THE DUBILIER CONDENSER Co., LTD., showed typical examples of their very extensive range of condensers for all wireless purposes. Notably a precision variable air condenser and several forms of standard condensers variable in steps. Improved forms of Mansbridge condensers were on view along with a new form of mica condensers for capacities of .02 to .3μF. An anti-interference unit, designed primarily for use in conjunction with small domestic motors, such as fans, etc. (especially when such apparatus is in use close to the wireless receiver), was also an interesting accessory. Amongst other accessories noted were a mica insulator and an R.C. coupling unit, while an electrostatic pickup was demonstrated in operation on a Rice-Kellogg loud-speaker.



Marconi Four-valve Short-wave set, in which one stage of neutralised H.F. amplification is employed. A doublet aerial is connected to a feeder box (not shown) which allows the receiver to be operated at almost any distance.

The stand of **The Edison Swan Electric Co.** was devoted entirely to valves of all classes and to the well-known Pointolite lamp, now shown in its latest form.

The Igranic Electric Co., Ltd., showed an extensive range of radio components, a new component being a " Lokvane " square law condenser. Outfits for definite set construction included a " Neutro-Regenerative " short wave amplifying kit, a 7-valve supersonic kit, etc. A range of eliminators for D.C. and A.C. work and other wireless set components were also on view.

Phillips Lamp Co., in addition to a number of X-ray tubes, had on view a new metal hot cathode rectifier valve, suitable for voltages up to 130,000 v.

Venner Time Switches, Ltd., showed their " Venanto " time switch for wireless broadcast receivers, along with a range of selenium cells.

Amongst other matters of general wireless interest were the resistances and controls of **Messrs. Isenthal & Co., Ltd.**, and of **The Zenith Electric Co., Ltd.**, a very complete range of batteries for L.T. and H.T. at the stand of the **Fuller Accumulator Co.**, and the rotary transformer of **The ML Magneto Syndicate, Ltd.**

RESEARCH AND EXPERIMENTAL SECTION.

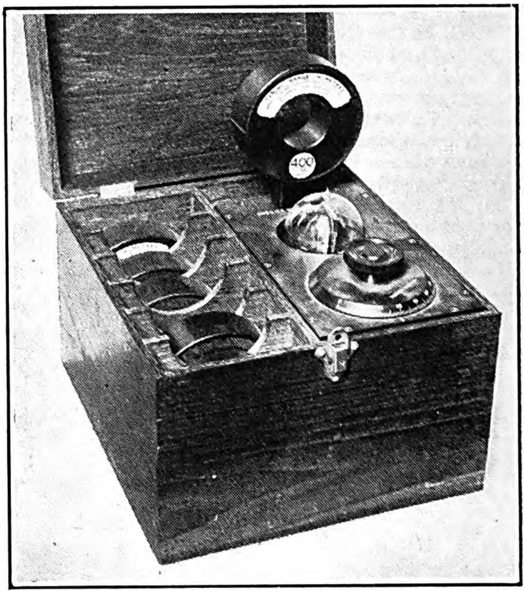
Following the lines introduced last year, a Research and Experimental Section again showed recent developments, lecture experiments, historical exhibits, etc.

In this section the most interesting features from a wireless point of view were a new primary wet cell by **Mr. A. M. Codd**, using zinc and carbon with a solution of ferri-chloride. This is claimed to be suitable for dull emitters as well as for domestic appliances, etc.

The **G.E.C. Research Laboratories** showed a new type of photo-electric cell, a simple means of using photo-electric cells; and a method of maintaining a valve filament at constant voltage, whether the anode is energised or not.

Mr. E. B. Moullin showed three new forms of high-range thermionic voltmeters, one of particular interest giving measurement of either peak or R.M.S. voltage.

Dr. D. Owen demonstrated the use of a magnetron to show the tune of establishment of current in an inductive field.



Dubilier Wavemeter, in which the glowing of a neon lamp indicates resonance.

The Gramophone Co., Ltd. (Research Dept.), had a highly interesting exhibit showing the application of electrical analogies to acoustic design. The sound box shown was of the latest form, with its electrical equivalent circuits, both treated from the point of view of a band-pass filter network.

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

Die Störung des elektromagnetischen Feldes eines Senders durch Gebäude und Ähnliches (The disturbance of the electromagnetic field of a transmitter by buildings, etc.).—S. Klimke. (*Elekt. Nachr. Technik*, 4, pp. 458-482, November, 1927.)

Although this investigation of the action of buildings, etc., on the development of a transmitter's electromagnetic field deals mostly with quite local influences, the knowledge of the field structure obtained is of practical importance, particularly since the coming of broadcasting, in showing how receivers located in the vicinity of such a disturbed electromagnetic field are affected. The paper is divided into three sections, dealing firstly with theory, then with methods of measurement, and lastly with the measurements themselves.

I.—Theory.

A wave developing undisturbed in vacuo or air possesses an electric component E and a magnetic component H which are in phase and perpendicular to one another and to the direction of propagation. From an absolute point of view $E = H$. This follows from the condition that, for each point of the field, the energy content of the electric must equal that of the magnetic field. If both components are given in E.M.U., we have the constant relation

$$E = cH.$$

In practice only H is given in E.M.U., in gauss, the electric component being given in V/m. Employing these two units, we obtain the equation

$$H \text{ (gauss)} = \frac{10-4}{3} E \; (V/m).$$

These equations, however, only hold good when there are no conductors in the field: if these are present $E \neq H$ and one conductor can no longer be determined from the other. To find the new structure of the field, the effect of a conducting system on both the electric and magnetic fields is calculated at length. It is found, in general, that while a conductor screens its immediate surroundings from the electric field, absorbing, so to speak, the field within itself, the magnetic field only suffers change of direction, and is not attenuated except by a loop-like or latticed structure.

II.—Methods of Measurement.

To confirm the theoretical deductions experiments were carried out in the field of the Dresden transmitter, usually at a distance of 9 to 10 wavelengths away, though some tests were made quite near, within a quarter wavelength. The near electric measurements were made with a Seibt drawn-out coil, and the more distant ones with a small elevated antenna surmounted by a metal umbrella for concentrating the capacity, the copper-plated instrument box serving as counterpoise. The magnetic measurements were made with a frame aerial. Photographs of the apparatus are shown. The diagram of the circuit-arrangement is reproduced in Fig. 1 below:—

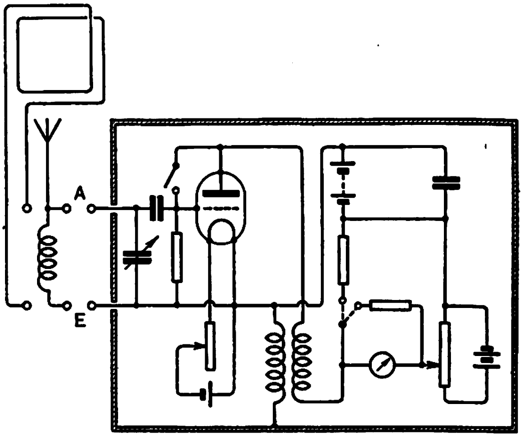


Fig. 1.

The apparatus was calibrated as a whole by means of a wire extended about 10 metres above the ground in which a known tension was produced. The calculation of the field-strength is explained in detail.

III.—The Observations.

The results are given of measurements made in the vicinity of a large number of different objects: the field found in the case of an iron lattice arc lamp-post is shown in Fig. 2 below:—

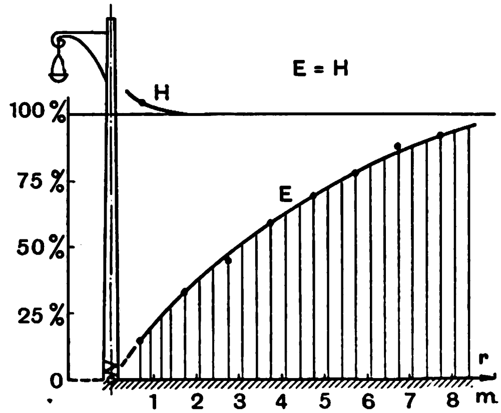


Fig. 2.

and compared with the theoretical disturbed electric and magnetic fields (Figs. 3 and 4).

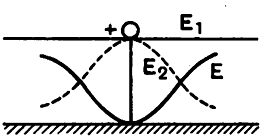


Fig. 3.

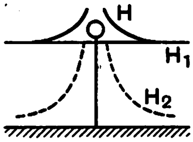


Fig. 4.

With wooden masts and sheds, no effect on the magnetic field was found and only a slight effect on the electric field, after rain, when the apparatus was brought quite close up (Fig. 5).

In the case of trees, no effect was found unless the apparatus was very near the tree, when an attenuation of the electric field by about 20 to 30 per cent. was generally found, independently of the size of the tree: no magnetic effect was ever observed. The measurements were carried out in March when the trees were still bare.

Besides these instances of a "pure dipole effect," examples are given of systems where the magnetic field is also affected, which include a large cable reel and the wire netting around a tennis ground.

Concerning the conductivity of buildings, those made of brick are found to be quite moderate conductors, as seen in the following diagram :—

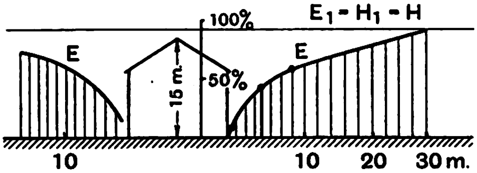


Fig. 5.

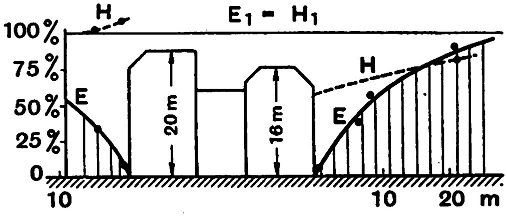


Fig. 6.

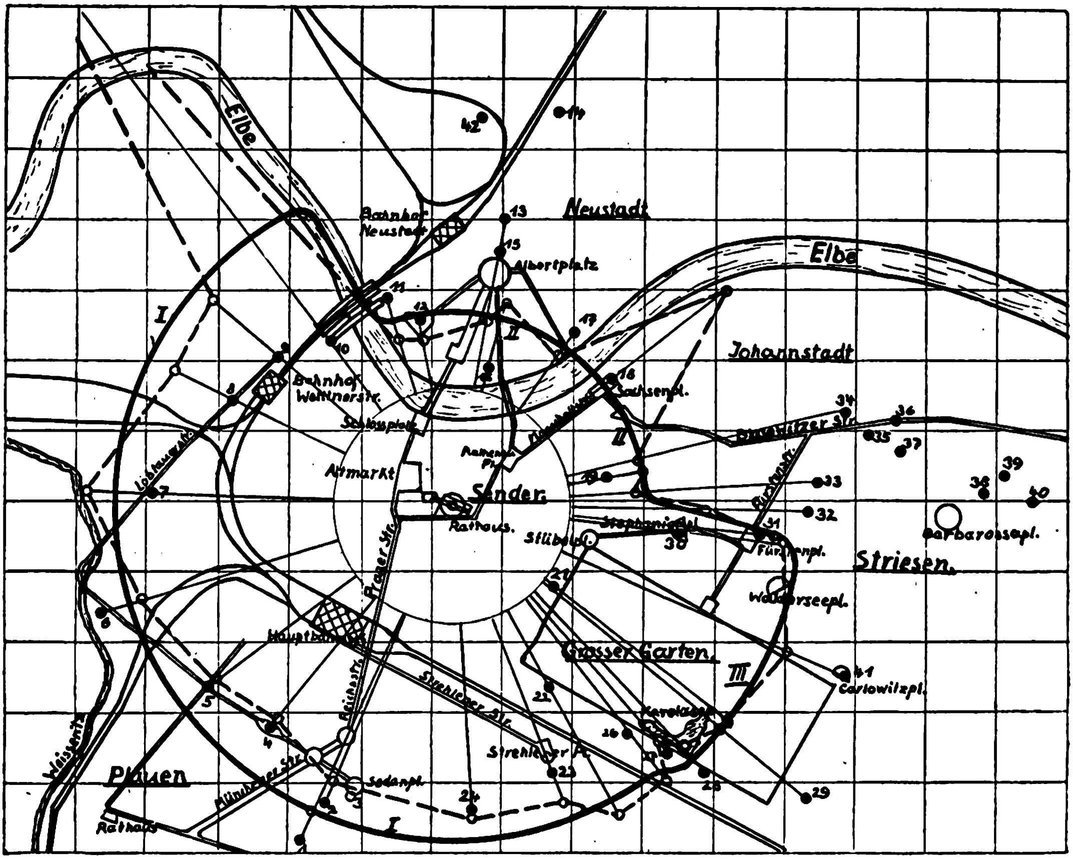


Fig. 7.

and those built of iron and concrete to affect both electric and magnetic fields as shown in Fig. 6.

Houses containing much iron act like a Faraday cage and prevent the electric field penetrating, particularly to the lower storeys: the electric field, as it were, steps over the houses; while the magnetic field penetrates to the ground, only its direction being distorted, except when it is attenuated by conducting loop-like or latticed structures.

Measurements made quite close to the Dresden transmitter, within its static field, likewise confirm the theoretical conclusions. The propagation curve of the electromagnetic curve is shown in Fig. 7.

The better propagation over the gardens on the right shows that houses absorb more field energy than trees. The low field values measured beyond the Elbe and partly also in an easterly direction are attributed to geological and ground-water conditions or a directivity of the transmitting antenna.

MESSUNGEN DER ELEKTROMAGNETISCHEN FELDSTÄRKE ZUR BESTIMMUNG DER REICHWEITE EINES RUNDFUNKSENDERS (Measurements of electro-magnetic field-strength to determine the range of a broadcast transmitter). (*E.T.Z.*, 48, pp. 1778-1779, 1st December, 1927.)

Abstract of a paper by S. Lemoine in *Tekniska Meddelanden från Kungl. Telegrafstyrelsen*, 1927, Nos. 2 and 3, p. 9.

In the summer of 1926, the Swedish Telegraph Department carried out measurements of the field-strength of the Karlsborg transmitting station, in different directions and at varying distances, with a view to determining the damping with changing conditions of the ground in the centre of Sweden, and estimating the range for detector reception of the Motala broadcast transmitter, then in course of construction. The observations were made chiefly along five radial lines, as shown in the map (Fig. 1).

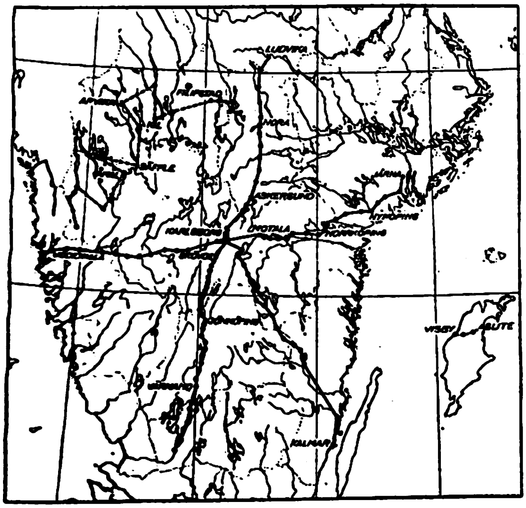


Fig. 1.

The experiments were based on Austin's formula (although this assumes transmission over water and in daylight) generalised in the following form :—

$$I_2 = 120\pi \frac{I_1 h_1 h_2}{d\lambda R} e^{-\frac{kd}{\sqrt{\lambda}}}$$

where, for a concrete case, all quantities are known except the damping k. For convenience, measurement was not made of the current strength in the receiving antenna I_2, but of the E.M.F. per unit length E. Writing the equation as follows :—

$$E = \frac{I_2 R}{h_2} = 120\pi \frac{I_1 h_1}{d\lambda} e^{-\frac{kd}{\sqrt{\lambda}}}$$

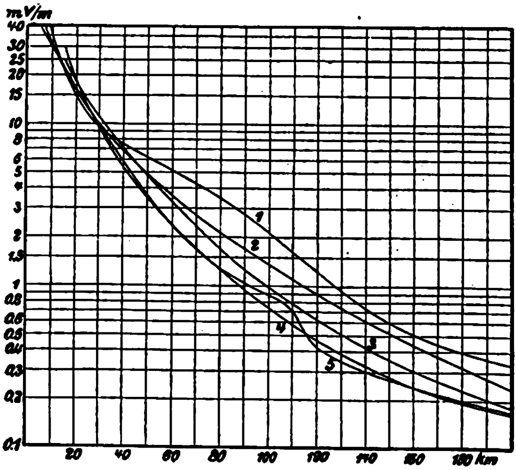


Fig. 2.
1. *Direction of Jönköping.*
2. „ „ *Uddevalla.*
3. „ „ *Nyköping.*
4. „ „ *Kalmar.*
5. „ „ *Ludvika.*

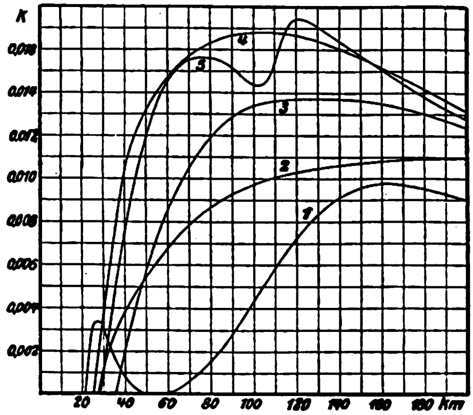


Fig. 3.

or, inserting the data for Karlsborg in amp. + kM, we have

$$Ed = 120\pi \frac{8{\cdot}5 . 0{\cdot}130}{1{\cdot}365} e^{-\frac{kd}{\sqrt{1{\cdot}365}}}$$

After plotting the readings on logarithm paper, the damping k can be calculated. The mean values of the field-strengths measured are compared in Fig. 2.

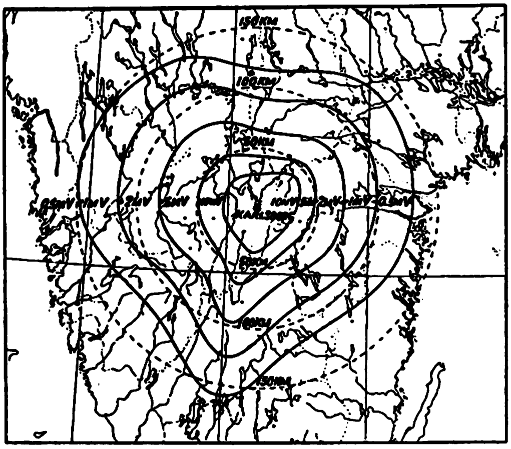


Fig. 4.

The ground conditions are so unhomogeneous that no equation can be drawn up that takes account of all of them. Fig. 3 shows the variation of the damping constants as obtained from these experiments, and Fig. 4 the equipotential curves for the field-strength of the Karlsborg transmitter.

THE ATTENUATION OF WIRELESS WAVES OVER LAND.—R. H. Barfield. (*E.W. & W.E.*, 5, pp. 25-30, January, 1928.)

Abstract of paper given before the Wireless Section, Institution of Electrical Engineers, 7th December, 1927.

DISCUSSION ON LONG-DISTANCE RECEIVING MEASUREMENTS AT THE BUREAU OF STANDARDS IN 1925 (L. W. AUSTIN).—K. Sreenivasan. (*Proc. Inst. Radio Engineers*, 15, pp. 1002-1003, December, 1927.)

RAUMSTRAHLUNG VON HORIZONTAL-ANTENNEN (Space Radiation from Horizontal Antennæ). —A. Meissner. (*Elekt. Nachr. Technik*, 4, pp. 482-486, November, 1927.)

A paper read at a meeting of the Heinrich Hertz Society, 5th September, 1927.

One of the most interesting problems of short-wave technique is the employment of horizontal antennæ and polarisation at transmission. Horizontal antennæ present the more striking innovation, evidently breaking with tradition in that all connection with the earth is entirely dispensed with, the whole radiation being quite detached from the earth's surface straight from the transmitter. The significance for wireless technique of the introduction of horizontal polarisation is shown by the widely distant and independent consideration made of the problem: first, by Alexanderson in America, then shortly afterwards by German experimenters, and in France Levi has a patent for horizontal antennæ dating from the same time. In Germany work was concentrated on horizontal polarisation and developed in a different direction from that in America and France.

Although the employment of horizontal antennæ and polarisation appears less specially remarkable when the idea of the transference of energy by pure space radiation has been grasped, the fact that when a horizontally polarised beam is sent out it must be received not as horizontally but vertically polarised is a new and for the present inexplicable phenomenon.

In the Telefunken Company's first experiments with horizontal transmitting antennæ, more than two years ago, horizontal receiving antennæ were always ordered for Buenos Ayres, but it was repeatedly reported that they would not work, and that reception could be effected only with a vertical antenna. Evidently a rotation of the plane of polarisation was taking place, similar to that found in optics, for which no unambiguous explanation has been given. We have to content ourselves with the apparently pretty general fact, that the plane of polarisation of a polarised radiation tends to place itself perpendicular to the surfaces of bodies over which it glides, if the bodies partly absorb the radiation or arrive at oscillating in resonance with it. Curves taken from a paper by Heising, Schelling and Southworth are reproduced, which show the gradual transition from horizontal to vertical polarisation with distance.

In the case of beam projectors employed by Marconi to concentrate the radiation, distinction has to be drawn between projectors for horizontal and those for vertical polarisation. With both projectors concentration in a horizontal plane is equally good and easy to obtain. With the vertical projector it is secured by placing several vertical antennæ, oscillating in the same phase, side by side in a plane, and with the horizontal projector by combining several horizontal antennæ oscillating in like phase, in a line. In both cases the greater the number of antennæ the greater the concentration. The gathering up of the radiation, concentrated in a horizontal plane in this way, into a beam—the concentration in a vertical plane—takes place in a different manner with the two projectors: in the case of the vertical projector it is effected by arranging several antennæ, a half-wave in length, oscillating in the same phase, one above the other, while with the horizontal projector this gathering up is brought about by constructing a parabolic reflector around the antenna. These methods of concentration were illustrated in the author's article in the *Zeitschrift* for September (these Abstracts, December, 1927, p. 766; *Proc. Inst. Radio Eng.*, 15, 11, p. 928) which should be referred to for further description of the investigation.

PROPAGATION OF SHORT WAVES DURING A SOLAR ECLIPSE.—E. J. Alway. (*Proc. Inst. Radio Engineers*, 15, pp. 998-1001, December, 1927.)

Special watch was kept at the Heliopolis receiving station, Egypt, in the early morning of 29th June, to observe the effect of the solar eclipse on the transmission of the 40–45 metre waveband.

After giving some notes of stations heard both in Europe and America, the writer concludes by assuming that, at least locally, a solar eclipse produces a pseudo-night-effect, this effect beginning with the eclipse, but finishing before it: that is, when the eclipse occurs in the morning.

THE RELATION OF RADIO RECEPTION TO SUNSPOT POSITION AND AREA.—G. W. Pickard. (*Proc. Inst. Radio Engineers*, 15, pp. 1004-1012, December, 1927.)

Communication from the International Union of Scientific Radio Telegraphy.

The purpose of this paper is to show that the central passage of sunspots does not exactly coincide with the associated reception disturbances and that the interval between the transit of the sunspots and the reception change varies both with the area of the sunspot group and with the period taken for investigation.

The results are represented graphically and discussed. The curves clearly show that the connection of reception with sunspots is far less intimate than its relation to magnetism, which is so definite as to require the conclusion that disturbances of reception and terrestrial magnetism arise from a common and nearby cause: an electrical change in our atmosphere. On the other hand, even when position as well as area is considered, the connection between individual sunspot groups and reception is quite insufficient to show that we are here dealing with cause and effect.

INFLUENCE DES SURFACES DE DISCONTINUITÉ ATMOSPHÉRIQUES SUR LA PROPAGATION DES ONDES COURTES (Influence of the atmospheric surfaces of discontinuity on the propagation of short waves).—G. Henri Huber. (*Comptes Rendus*, 185, pp. 934-936, 7th November, 1927.)

A series of observations was made in France on the service of meteorological transmissions from the dispatch boat, *Ville-d'Ys*, during its cruise to Norway and Iceland. The transmissions were made on 65 and 24 metres simultaneously and from the observations, carried out regularly six times a day, the following conclusions are drawn:

Surfaces of atmospheric discontinuity form an obstacle to the propagation of short waves; this is most distinct for the polar front properly so called, which often presents very sharp discontinuities; moreover, the obstacle is the more serious, the more marked the fraction of the front located between the two stations trying to communicate. In the case of a surface of discontinuity forming two dihedra with the ground, one pointed and the other obtuse, the emission of a station situated in the pointed dihedron is much less obstructed than its reception; it is seen that such a station could quite well not hear its correspondents beyond the front and yet be heard by them. Further, it seems that the nearer one of the two correspondents is to the front, the greater the obstacle presented to propagation.

ATMOSPHERICS.

THE RANGE OF ATMOSPHERICS.—(*Quarterly Journal of the Roy. Met. Soc.*, 53, pp. 327-400.)

A Report from the Committee on the Relation between Atmospherics and Weather.

Although the evidence set forth in this report is too conflicting for any certain conclusion to be drawn on the main issue, namely, the relation between atmospherics and weather, the Committee are of the opinion that the evidence decisively shows:—

(*a*) That the effective range of reception of very many atmospherics, heard on normal broadcast receivers, exceeds 3,000 km. or 1,850 miles, and reaches at least 7,000 km. or 4,500 miles.

(*b*) That there is no evidence of the presence of many atmospherics whose range is less than 200 km.; that such atmospherics, should they exist, never formed so much as 25 per cent. of the distribution on any of the occasions discussed.

(*c*) That the evidence obtained confirms previous experience in showing that cold fronts are of great importance in the origination of atmospheric disturbance.

(*d*) That the seventeen random samples considered in the report demand fuller examination of the meteorological environment.

(*Cf.* Mr. Watson Watt's observations, *Journ. Met. Soc.*, 52, p. 199, these Abstracts, January, 1927, p. 50.)

ATMOSPHERICS AT WATHEROO, WESTERN AUSTRALIA.—J. E. Cairns. (*Proc. Inst. Radio Engineers*, 15, pp. 985-997, December, 1927.)

Of nearly 1,000 atmospheric radiation waveforms observed over a period of nine days at the Watheroo Magnetic Observatory from 20th to 28th March, 1927, the most frequently occurring form was found to be a negative peaked quasi-periodic consisting of three "half cycles," the maximum field-change being associated with the second "half cycle." The mean duration and field-strength of this type, which occurred in 10 per cent. of all cases examined, were 3,458 μs and 0.139 volts per metre respectively. Reconstructed drawings of the most frequently occurring forms are given, as well as reproductions of actual sheets of observations.

The summer "roar" is shown to be most probably due to short-period, small-amplitude, almost continuous ripples, the period lying between 50 and 100 μs and the amplitude being approximately 0.008 volts per metre. The static "rattle" noted by De Groot in the Dutch East Indies is probably due to ripples similar to these.

Negative atmospherics predominated, the only notable positive being an aperiodic of relatively long duration, this form being almost invariably associated with lightning. Quasi-periodics were more numerous than aperiodics, and the peaked form occurred in greater numbers than the rounded. The symmetrical negative peaked aperiodic was noteworthy, because of the shortness of its duration, 786 μ sec. All atmospherics seen on the oscillograph screen were accompanied by a noise in a radio receiver.

Semi-permanent field-changes were fairly numerous, the negative change occurring far more frequently than the positive, the thunderstorms producing these changes being usually over 50 km. distant.

WIRELESS AND METEOROLOGY.—(*Wireless World*, 21st December, 1927, pp. 813-816.)

Account of the observation of atmospherics carried out on the U.S.S. *Kittery*, which enabled the progress of hurricanes in the West Indies to be traced, and conclusively proved Lieut. Kincaid's theory that the strength of static is proportional to the rate of change of atmospheric pressure.

PROPERTIES OF CIRCUITS.

THE STABILITY OF THE TUNED-GRID TUNED-PLATE H.F. AMPLIFIER.—R. T. Beatty. (*E.W. & W.E.*, 5, pp. 3-15, January, 1928.)

THE RELATION BETWEEN PLATE CURRENT AND PLATE POTENTIAL IN THE THERMIONIC AMPLIFIER, DEDUCED FROM THE ORBITAL MOTION OF THE ELECTRONS.—L. E. McCarty. (*Physical Review*, 30, pp. 878-892, December, 1927.)

An expression for the plate current in terms of the grid and plate potentials and geometrical dimensions of a parallel plate type of thermionic amplifier is deduced from the orbital motion of the electrons. The amplifier is assumed to consist of a charged grid of small parallel wires of infinite length situated between two infinite parallel plates at distances from it comparable with the distance between consecutive grid wires, the whole enclosed in a vacuum of such magnitude that the mean free path of the electrons is large in comparison with the distance between the plates. The effect of the space charge is neglected.

Equations giving the force acting on an electron situated at any point in the field due to the charge on the grid and the potential difference between the anode and cathode are derived. These expressions are evaluated and tabulated for various points of the field and the orbits of a number of electrons computed by a process of numerical integration. An empirical relation is found to exist between the distance of the starting points of the electrons, whose orbits turned at a common plane, from the rectilinear projection of a given grid wire on the cathode, and a certain parameter involving the charge per unit length of grid wire, the plate potential, and the geometrical dimensions of the amplifier. Inasmuch as the plate current is determined by the number of electrons reaching the plane where the plate is assumed to be located, before turning back; and since the turning point depends on the starting position of the electron relative to the grid wires, this empirical equation furnishes the required relation between current and plate potential, grid charge, and the geometrical parameters.

Two cases are considered: (*a*) a negatively charged grid, and (*b*) a positively charged grid. On account of the greater practical importance of the first case most of the orbits computed are for a negatively charged grid. After substituting for the charge on the grid in terms of the potentials and capacity coefficients, the final equation for this case, assuming the cathode to be at zero potential and at a distance from the grid equal to the distance between consecutive grid wires, is

$$I_P=I_0\{1-2C/[a(kV_P+hV_G)/2(aV_P-SV_G)-\mu_0]\}$$

where I_0 represents the saturation current, V_P and V_G the plate and grid potentials respectively, the other quantities being constants of the apparatus.

BACK COUPLING IN L.F. AMPLIFIERS.—M. G. Scroggie. (*Wireless World*, 14th December, 1927, pp. 782-786.)

Discussion of the effects of anode supply impedance on the performance of amplifiers.

RESISTANCE AMPLIFIERS.—P. Tyers. (*Electrical Review*, 18th November, 1927, p. 885.)

A letter replying to Mr. Phillips' discussion, in the *Review* of 23rd September, of the writer's article in the *Review* of 9th September.

REACTION AND SELECTIVITY.—A. P. Castellain. (*Wireless World*, 7th November, 1927, pp. 757-758.)

An inquiry as to whether the effects of circuit resistance can be entirely annulled by reaction.

RECEPTION.

QUANTITATIVE DETERMINATION OF RADIO-RECEIVER PERFORMANCE.—(*Journ. Amer. Inst. E.E.*, 46, p. 1464, December, 1927.)

Discussion at Pittsfield meeting of Mr. Oakley's paper published in this Journal for May, 1927, p. 487.

RECTIFIERS AND SMOOTHING CIRCUITS.—F. Record and I. H. Holmes. (*Wireless World*, 28th December, 1927, pp. 841-843.)

An experimental study of input and output wave forms by means of the Duddell oscillograph.

A NOTE ON VOLUME CONTROL.—(*Wireless World*, 28th December, 1927, p. 852.)

THE LAST STAGE.—(*Wireless World*, 30th November, 1927, pp. 739-742.)

Some observations on the need for power in order to secure quality, and a consideration of the relative merits of super-power valves, valves in parallel, and valves in push-pull.

THE POWER SUPPLY OF WIRELESS SETS.—G. F. J. (*Electrical Review*, 18th November, 1927, pp. 856 857.)

The "battery-less" receiver: some experiences of an engineer who constructed a set incorporating three valves with indirectly heated filaments.

SUR UNE VÉRIFICATION DE LA THÉORIE DES DÉTECTEURS ET REDRESSEURS À CONTACT (On a verification of the theory of contact detectors and rectifiers).—M. Dubar. (*Comptes Rendus*, 185, pp. 1023-1024, 14th November, 1927.)

Pélabon's experiments have shown that an electric current can pass through an insulating layer of sufficiently small thickness separating two conductors; but in general the whole thus constituted is endowed with different conductivity according to the direction of the current. When the opposite faces do not present significant differences of curvature, electronic theory indicates that the current will pass more easily from the conductor which is the poorer in free electrons to the richer conductor than in the reverse direction. The author describes experiments supporting this theory. An extremely thin insulating film of silica was deposited by electrolysis on the surface of a lump of silicon, and then graphite placed in contact with the film and pressure applied. The current-voltage curve of the complex conductor thus obtained was plotted. With the same voltage, the current in the direction silicon-graphite was very much greater than that in the reverse direction, and alternating current of relatively high frequency was rectified. The direction of greater conductivity is in accord with theory, silicon being much more resistant than graphite and consequently poorer in free electrons. It is curious to note that if an electrolytic rectifier is made, employing the same piece of silicon and a carbon pencil in dilute sulphuric acid, the direction of the current is reversed, that is from the carbon to the silicon. This is explained by the fact that the relative proportion of free electrons is changed round, the electrolyte not containing any (but only ions) while the silicon does contain free electrons, ts conductivity being of a metallic nature.

VALVES.

The Cossor Screened Valve.—(*Wireless World*, 21st December, 1927, pp. 817-818.)

The valve's characteristic curves are shown and practical hints are given for best conditions of working.

DIRECTIONAL WIRELESS.

On the Wireless Beam of Short Electric Waves (VIII).—S. Uda. (*Journ. Inst. Elect. Eng. Japan*, 471, pp. 1092-1100.)

A paper considering the horizontally polarised wave projector. The action of horizontal wave directors is studied in detail and compared with that of vertical wave directors (*J.I.E.E. Japan*, No. 467; these Abstracts, October, 1927, p. 639). In the present case, of course, each of the wave reflector and director rods is placed horizontally along the ground. It is pointed out that the length of the wave directors is the most important factor in improving directivity and consequently increasing the energy received. The results of field measurements are given and polar diagrams shown, proving that a sharp beam of horizontally polarised waves was produced.

In these experiments the wavelength employed was 441 cms., the length of each director being 200 cms. and the distance apart 150 cms. The field was measured by means of a horizontal receiving antenna which included a thermo-couple and a micro-ammeter.

On the Wireless Beam of Short Electric Waves (IX).—S. Uda. (*Journ. Inst. Elect. Eng. Japan*, 472, pp. 1201-1219.)

The effects of wave reflector and director on the sending antenna circuit are studied theoretically with reference specially to the following points:

1. Effect on antenna current.
2. Effect on antenna power.
3. Wave reflector and director characteristics at constant antenna current and power.
4. Directive polar diagrams at constant antenna current and power.

Some results obtained experimentally are also shown and compared with those calculated.

MEASUREMENTS AND STANDARDS.

On the Bridge Type of Valve Voltmeter.—I. Yamamoto and K. Morita. (*Journ. Inst. Elect. Eng. Japan*, 471, pp. 1051-1064.)

Description of a new instrument for measuring very small alternating voltages, consisting of a balanced high resistance bridge, two symmetrically placed triode rectifiers, and a d'Arsonval galvanometer.

If a small voltage is applied to one diagonal of the bridge, and an auxiliary voltage of the same frequency to the other diagonal, the galvanometer gives a deflection proportional to the scalar product of these two voltages. The voltage sensitivity of the arrangement can be varied by choosing the auxiliary voltage over a wide range, the maximum sensitivity obtained in this experiment being 2.4 mm. for one millivolt with an auxiliary voltage of 8 volts.

The apparatus can also be conveniently used for the very precise comparison of radio frequencies, a difference of one-tenth of a cycle being detectable by the authors' method.

The Power-factor and Capacity of the Electrodes and Base of Triode Valves with Special Reference to Their Use in Thermionic Voltmeters.—G. W. Sutton. (*Proc. Phys. Soc.*, 40, pp. 14-22, December, 1927.)

The paper discusses the conditions under which a three-electrode valve-voltmeter should be operated to ensure a minimum power consumption, and at the same time to give indications closely proportional to the square of the input voltage. A simple method of adjusting the operating voltages to fulfil the necessary conditions is described.

This paper is briefly referred to in *E.W. & W.E.* for January, 1928, p. 16.

Impiego dell'Oscillografo nello Studio delle Correnti Radiotelegrafiche (The employment of the oscillograph in the study of the currents of radiotelegraphy).—G. Pesson and T. Gorio. (*L'Elettrotecnica*, 25th November, 1927, pp. 849-856.)

Description of the apparatus and method, showing several typical oscillograms.

A Mechanical Harmonic Analyser for Cathode Ray Oscillograms.—C. F. Wiebusch. (*Journ. Opt. Soc. Amer.* and *Rev. Sci. Instr.*, 15, pp. 355-358, December, 1927.)

Description of an instrument which will analyse oscillograms obtained from the cathode ray oscillograph when the reference field is sinusoidal, and is adjustable to take care of oscillograms of various sizes. The analyser can also be used for curves plotted on a uniform base. The particular instrument described was made to analyse up to and including the tenth harmonic.

ABBREVIATED METHOD FOR CALCULATING THE INDUCTANCE OF IRREGULAR PLANE POLYGONS OF ROUND WIRE.—V. J. Bashenoff. (*Proc. Inst. Radio Engineers*, 15, pp. 1013-1039, December, 1927.)

A paper containing the first part of an investigation on the design and use of closed aerials (calculation of the inductance for single-turn aerials). Two methods are given for determining the inductance for closed aerials and, in general, plane figures of any shape, having no re-entrant angles. The first method is based on the author's supposition of the practical equivalence of the inductance of any figure and the inductance of a right triangle or rectangle, having area and perimeter equal to those of the given figure. The second method is a development of the basic assumption of the first, and results in the derivation of a simple formula for all possible figures, including curved ones.

Numerous tests of the correctness of both methods by practical measurements on closed aerials with a height of the point of support from 65 down to 2 metres have fully confirmed the author's conclusions.

PIEZO-ELECTRIC RESONANCE AND OSCILLATORY PHENOMENA WITH FLEXURAL VIBRATIONS IN QUARTZ PLATES.—J. R. Harrison. (*Proc. Inst. Radio Engineers*, 15, pp. 1040-1054, December, 1927.)

A method is given of obtaining flexural vibrations from piezo-electric quartz plates together with the equations for flexural vibrations in quartz. Crystal mountings for obtaining best results with the first, second, and higher modes of flexural vibration are developed. Description is also given of the use of the crystal at flexural frequencies in the oscillator circuits of Cady and Pierce, and the luminous phenomena obtained when resonating in a partially evacuated chamber with different types of mountings. Without employing unusually long plates the range of frequencies obtainable is extended into the audible range.

Among the problems still to be solved are the temperature coefficient of frequency and logarithmic decrement for the various modes of flexural vibration as well as constancy of frequency under variations of load and constants of the electric circuit. Investigation is still in progress, a report of which will be communicated later.

SUBSIDIARY APPARATUS.

STORY OF THE HORNLESS LOUD-SPEAKER.—(*Wireless World*, 21st December, 1927, pp. 806-810.)

An historical survey of the development of free-edge, fixed-edge and inertia-controlled cone loud-speakers from 1879 to the present day.

STATIONS: DESIGN AND OPERATION.

5SW, CHELMSFORD.—(*Wireless World*, 30th November, 1927, pp. 737-738.)

Illustrated account of the new 20 kW experimental transmitter at Chelmsford for empire broadcasting, working at present on a wavelength of 24 metres.

GENERAL PHYSICAL ARTICLES.

SUR LE RÔLE DE L'OZONE DANS L'ATMOSPHERE (On the part ozone plays in the atmosphere).—J. Lévine. (*Comptes Rendus*, 185, pp. 962-963, 7th November, 1927.)

The most distinct result of the first year of a system of simultaneous observations of the ozone at different places is that the richness of the atmosphere in ozone is closely linked with the distribution of atmospheric pressure, ozone being more abundant in depressions than in anticyclones.

THE PHOTOELECTRIC CONDUCTIVITY OF SULPHUR.—B. Kurrelmeyer. (*Phys. Rev.*, December, 1927, pp. 873-910.)

Experiments are described, the results of which suggest that sulphur has a polar axis due to atomic asymmetries and should show the piezo- and pyro-electric effects.

A THEORY OF IMPERFECT SOLID DIELECTRICS.—M. G. Malti. (*Journ. Amer. Inst. E.E.*, 46, pp. 1373-1380, December, 1927.)

Abridgment of a thesis summarising the experimental facts regarding the anomalous behaviour of solid insulating materials under varying conditions of potential, time, temperature, frequency, humidity, ionising radiations and various other factors; and establishing hypotheses accounting in a general way for the behaviour observed.

STUDY OF THE HIGHER NATURAL OSCILLATIONS OF SOLENOIDAL COILS.—I. Yamamoto. (*Journ. Inst. Elect. Eng. Japan*, 471, pp. 1101-1129.)

Report of an experimental investigation of the higher natural electrical oscillations of solenoidal coils of finite length.

The coil specimens under experiment, all wound on octagonal frames made of ebonite bars with cotton-covered copper wires, included fourteen different coils of the single layer type.

The higher natural wavelengths were measured when both ends of the coil were free and also when one end was earthed, and it was concluded from the experimental results that the ratio of the fundamental natural wavelength λ_1 to the higher natural wavelength of the mth order λ_m could be practically represented by a linear equation

$$\lambda_1/\lambda_m = 1 + a(m - 1),$$

where the coefficient a is a function of the dimension ratio $h/2_r$ of the coil.

A qualitative explanation of these results is given, taking into account the mean propagation velocity of electrical disturbance along the length of the coil.

NEW METHODS OF ELECTRICALLY MAINTAINING MECHANICAL OSCILLATIONS.—J. H. Vincent. (*Nature*, 31st December, 1927, p. 952.)

An outline of methods which may find application such as the providing of sources of oscillations and frequency standards.

CONSEQUENCES OF A MATRIX MECHANICS AND A RADIATING HARMONIC OSCILLATOR WITHOUT THE QUANTUM POSTULATE.—A. Press. (*Phil. Mag.*, 4, pp. 1249-1261, December, 1927.)

Phénomènes Optiques Présentés par le Quartz mis en Vibration Piézo-Électrique (Optical phenomena presented by quartz set in piezo-electric vibration).—R. Moens and J. E. Verschaffelt. (*Comptes Rendus*, 185, pp. 1034-1036, 14th November, 1927.)

Demonstration of High-frequency Fluctuations in the Intensity of a Beam of Light.—C. O. Browne. (*Proc. Phys. Soc.*, 40, p. 36, December, 1927.)

Brief description of an experiment, due to Prof. Kerr Grant, in which a beam of light is made to fluctuate in intensity at radio frequencies in synchronism with the piezo-electric oscillations of a quartz crystal.

Free Motion in the Wave Mechanics.—C. G. Darwin. (*Proc. Roy. Soc.*, A.117, pp. 258-293, December, 1927.)

Whereas hitherto the wave mechanics has mostly been applied to a study of stationary states, the present paper deals with its application to cases where there is a *progress* of events. After a review of principles and a description of the new way in which motion must be regarded, the following problems are discussed :—

The free motion of an electron under no forces.
The motions of an electron in uniform electric and magnetic fields.
The motion of an electron in an atom.
The motion of an atom in a uniform magnetic field.
The Stern-Gerlach effect.
The motion of the spinning electron.

Thermodynamics, Wave-Theory, and the Compton Effect.—C. V. Raman. (*Nature*, 31st December, 1927, p. 950.)

MISCELLANEOUS.

Colour by Wire or Radio.—(*Journ. Amer. Inst. E.E.*, 46, p. 1380, December, 1927.)

A new invention for matching colours is reported at the Massachusetts Institute of Technology. The colour specimen is placed in a holder close to a high-power electric lamp. Light is alternately reflected from it and from a block of magnesium carbonate, the whitest of the world's substances, and variation of reflection from these two surfaces is registered by a photo-electric cell and transmitted in electrical impulses by either wire or radio. Exact reproduction of any shade can be made without the possibility of visual error, thus advancing the industries from dependence upon the human eye.

Quantitatives über Strassenbahnstörungen des Rundfunkempfanges (Quantitative results on the disturbance of broadcast reception by trams).—W. Bernitt. (*Zeitschr. f. techn. Physik*, 8, pp. 410-421.)

Description of experiments in which the intensity of the noise disturbing radio reception, that occurs when the trolley of a street electric tram is taken off, is compared with the intensity of a standard source of disturbance, by means of a travelling receiver. Investigation is made of the disturbances along and perpendicular to the line, of the influence of the material of which the trolley is made and the insertion of condensers.

The Movietone.—W. I. G. Page. (*Wireless World*, 14th December, 1927, pp. 789-792.)

British Time Signals from Rugby, GBR.—(*Wireless World*, 28th December, 1927, p. 843.)

Account of this new service to navigators, astronomers and geographical expeditions.

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPAGADO DE ONDOJ.

La Maldenseco de Senfadenaj Ondoj Super la Tero.—Resumo de prelego legita de S-ro. R. H. Barfield, M.Sc., A.M.I.E.E., ĉe la Senfadena Sekcio, Institucio de Elektraj Inĝenieroj, Londono, je 7a Decembro, 1927a.

La prelego priskribas mezuradojn de intenseco faritajn per portebla aparato je normalaj sendadoj el la Londona Brodkasta Stacio, laŭlonge de sep malsamaj direktoj, kaj je distancoj de 5 ĝis 100 mejloj.

La aparato kaj mezura sistemo estas priskribitaj kaj la rezultkurvoj montritaj. Oni utiligis ĉi tiujn por konstrui konturan mapon de kampaj fortecoj, kaj ili estas poste reduktitaj al norma formo kaj komparitaj kun teoriaj rezultoj kalkulitaj laŭ la laborado de Sommerfield pri la teorio de maldenseco. Oni montras, ke la maldenseco estas pli granda laŭ unuj direktoj, ol laŭ aliaj, estante rimarkinde pligranda laŭ direkto Suden el Londono, ol laŭ direkto Norden, dum laŭ ĉiuj direktoj la maldenseco estas pligranda ol la teorio antaŭdiras.

La aŭtoro tiam sugestas, ke ĉi tiu pligrandigita maldenseco estas kaŭzita de l'efekto de arboj, la angla kamparo estante plejparte dense arbita. Oni priskribas eksperimentojn pri mezurado de la efekto de arbo, kaj esprimo estas derivita montranta la nombron da arboj por unuo-areo bezonita por sorbi tiom da potenco, kio egalas tion sorbitan de

la tero. Efektivaj nombradoj de l'arboj en la diversaj distriktoj montras, ke la Suda regiono estas plidense arbita, kaj oni konkludas, ke la efekto de arboj multe helpos klarigi la diversajn efektojn, kaj la forirojn for de la teoriaj valoroj.

Raporto pri la diskutado, kiu sekvis la legadon de la prelego, estas ankaŭ donita.

PROPRECOJ DE CIRKVITOJ.

La Stabileco de la Altfrekvenca Amplifikatoro kun Agordita Krado kaj Agordita Plato.—R. T. Beatty.

En la enkonduko la aŭtoro atentigas la mankon de kvanta traktado pri la valoro de reakcio, kaj ke, per ŝirmitaj valvoj, altfrekvencaj amplifikatoroj povas nun esti konstruitaj kun perfekta stabileco kaj kun la reakcio regita kaj kalkulebla. Oni povas ĉiam faciligi la kalkuladon, anstataŭigante rezistancojn per la interrespondaj konduktancoj.

De la ekvivalento de tipa paralela cirkvito, li nun alpaŝas al la okazo de la cirkvito kun agordita krado kaj agordita plato, kaj tiam disvolvigas ekvaciojn de l'amplifikatoro. Oni montras, ke A estas la amplifeco, kiu ekzistus se retro-kuplo estus for, kaj la cirkvitoj agorditaj laŭ la signalo, dum H estas valoro dependanta de cirkvitaj konstantoj. F kaj H povas esti prezentitaj sur parabolo, per kio la gajno de reakcio estas legebla per ekzameno. Li tiam disvolvigas la geometrian signifon de H & F, montrante la konstruon de la parabolo aludita. Numera ekzemplo estas donita, kaj la alproksimiĝo al malstabileco diskutita, dum la tuta ŝtupa gajno kaŭze de A kaj F estas taksita.

La rezonado (ĝis nun limigita al valvo, traktita kiel norma en la prelego) estas tiam etendita por apliki al iu ajn valvo. La maksimuma ŝtupa gajno G (kun fiksaj kondensatoroj kaj varieblaj bobenoj) estas poste diskutita kaj por la norma kaj por iu ajn valvo, dum fine la rezonado estas aplikita al la plikutima praktika ekzemplo kovri vastan skalon de agordado per bobenaro kun variebla kondensatoro. Ĉi tiu ekzemplo estas ilustrita per "ŝtupetara" serio de kurvoj, ĉiu "ŝtupo" interrespondanta al la agorda skalo de aparta paro da similaj bobenoj uzitaj en la kradaj kaj anodaj cirkvitoj respektive.

HELPA APARATO.

La Kupro-oksida Rektifikatoro.

Redakcia artikolo traktas pri ĉi tiu tipo de seka rektifikatoro. Se oni formas tavolon de oksido sur folio de kupro kaj faras kontakton per peco de plumbo premita kontraŭ la oksido, la rezisteco kontraŭ kurento pasanta de plumbo al kupro estas malpli ol tio en la kontraŭa direkto. Por aplikita tensio de 5 aŭ 5 voltoj la proporcioj de ĉi tiuj rezistecoj estas ĉirkaŭ 12,000.

Karakteriza kurvo de la rektifikatoro estas donita, kaj la konstruo de l'rektifikatoro ilustrita, dum diagramoj estas ankaŭ donitaj pri la utiligo de grupoj da ĉi tiuj rektifikatoroj por bateria ŝargado, kun fotografaĵoj de komercaj produktaĵoj.

La Korekteco kaj Normigada Daŭreco de Varieblaj Aer-kondensatoroj por Precizecaj Ondometroj.—W. H. F. Griffiths.

La aŭtoro unue atentigas, ke la korekteco de subnorma ondometro estas ĉiam limigita de la konstanteco de ĝia variebla aera kondensatoro kaj de ĝia grado de leĝo-konformeco.

En Parto I de l'artikolo, la aŭtoro diskutas ĉi tiujn dubecojn pri kapacito. Montrinte unue la pligrandan alproksimiĝon al konstanteco de dekremento obtenita per utiligo de variebla kondensatoro kaj fiksaj bobenoj (kontraŭ fiksa kondensatoro kaj varieblaj induktancoj), li nun diskutas la malfacilaĵojn de variebla kondensatora konstruado. Estas necese, ne nur, ke la platoj estu perfekte paralelaj, sed ankaŭ, ke ĉiu mova plato rotaciu ĝuste meze inter sia paro da fiksaj platoj (vidu S-rojn. Braillard kaj Divoire, en *E.W. & W.E.*, Junio, 1927a). La ĝenerala efekto de interspac-egaligo estas poste diskutita detale, kaj rilate al daŭreco kaj rilate al leĝo-konformeco, la diskutado estante bone ilustrita per grafikaĵoj. Ekzemplo de moderna precizeca kondensatora korekteco estas ankaŭ citita kaj ilustrita.

En Parto II la aŭtoro priskribas novan desegnon de variebla kondensatoro. La necesega trajto estas, ke apudaj dielektrikaj interspacoj estas en seria formo, anstataŭ paralela, kaj estas ankaŭ komplementaj. Laŭ sia plej simpla formo tia kondensatoro konsistas el tri platoj, du fiksaj kaj unu mova. La du fiksaj platoj estas izolitaj unu for de l'alia, kaj agas kiel la bornoj de l'instrumento. La mova plato estas interfoliita inter ili kaj estas izolita for de ambaŭ, kaj oni montras, ke la kapacito estas inverse proporcia je la sumo de la du grupoj, kiu restas konstanta, ĉu la mova plato estas centrigita aŭ ne. La aranĝo estas montrita, aplikite al pligranda nombro da platoj, utiligante similan principon.

La artikolo estas daŭrigota.

La Potenca Faktoro kaj Kapacito de l'elektrodoj kaj fundo de Triodoj.

Jen raporto pri prelego legita kun ĉi-supra titolo de S-ro. G. W. Sutton ĉe la Fizika Societo de Londono. Oni diras ke, aparte ĉe valva voltmetra aranĝo, la valvtenilo kaj fundo eble enkondukos konsiderindajn perdojn. Antaŭa sugesto (de Hartshorn kaj Jones), ke la vitra parto estas plikulpa ol la miksaĵa fundo, ne estas subtenita de S-ro. Sutton. Ĉi tiu aŭtoro donas ciferojn pere de Tabelo montranta kapaciton lau $\mu\mu$F kaj Potencan Faktoron por kelkaj malsimilaj valvoj kun aŭ sen iliaj fundoj.

DIVERSAĴOJ.

Resumoj kaj Aludoj.

Kompilita de la Radio-Esplorada Komitato (*Radio Research Board*), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

Indekso.

La nuna numero enhavas Indekson por Volumo IV, kompletigita per la numero de Decembro 1927a.

La Indekso estas dividita laŭ tri partoj :—

I Ĝenerala Indekso (Titoloj),
II Nomoj de Kontribuintoj,
III Resumoj kaj Aludoj.

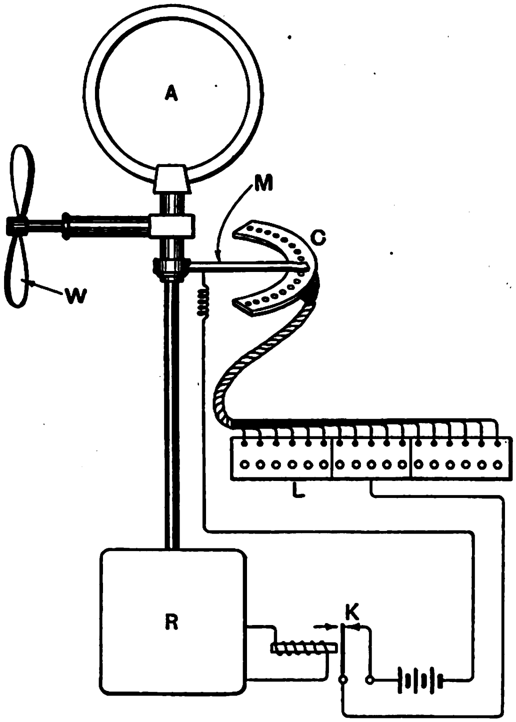
Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

AIRCRAFT D.F. INSTALLATION.

(*Convention date* (*Germany*), *20th March*, 1926. *No.* 267969.)

In order to simplify the process of taking bearings by wireless, whilst in the air, a D.F. installation is designed to give the pilot the required information automatically by means of a flash-lamp indicator. The loop aerial *A* is driven either by a windscrew *W*, or from the main propeller, so that it swings constantly to and fro over an angle of say 90 degrees. Somewhere within this sector it will bear directly on the transmitter station, in which position no signal energy is received. At this critical point a flash-lamp illuminates as follows :—



Attached to the rotating shaft of the frame aerial is an arm *M* which sweeps over a series of contacts *C*. These are connected through a corresponding bank of indicator lamps *L* in a local circuit containing an electromagnetically-controlled contact *K*. So long as there is any pick-up energy in the aerial *A*, the output from an amplifier *R* is sufficient to maintain the contact points *K* open. At the precise point of zero reception, however, the amplifier output falls, the contact *K* closes, and the local circuit operates to illuminate the particular lamp *L* which corresponds to the position of the arm *M*, thus giving the pilot a visual indication of the required bearing. Instead of using the lamps *L*, a single Neon tube may be mounted to rotate over a compass dial, in synchronism with the loop aerial, the point of minimum reception being indicated by the sudden extinction of the Neon glow as the voltage from the amplifier drops

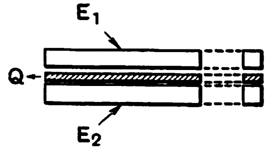
Patent issued to the Telefunken Co.

LUMINOUS FREQUENCY-INDICATORS.

(*Convention date* (*Germany*), *15th May*, 1925. *No.* 252170.)

A rod *Q* of rock crystal, some centimetres in length and a few square millimetres in cross-section, rests freely on a lower metal electrode E_2. A narrow space filled with rarefied air or other gas separates it from an upper metal electrode E_1. Under these conditions when the crystal is excited by electric oscillations corresponding to its fundamental frequency, the resulting piezo-electric voltage acts to ionise the rarefied air and so produces a luminous glow.

If the exciting frequency is the *n*th harmonic of the fundamental crystal frequency, *n* evenly-spaced bands or zones of light appear in the vacuous space. In this way the effect may be utilised to give a visual indication of the presence of any particular frequency, within the limits of the crystal dimensions. By mounting together several crystal rods, cut to different sizes, the arrangement can be used to give a visual indication, for example, of fluctuations in the carrier wave-length of a transmitting station, any variation from the allotted frequency being accompanied by a shifting of the luminous bands.

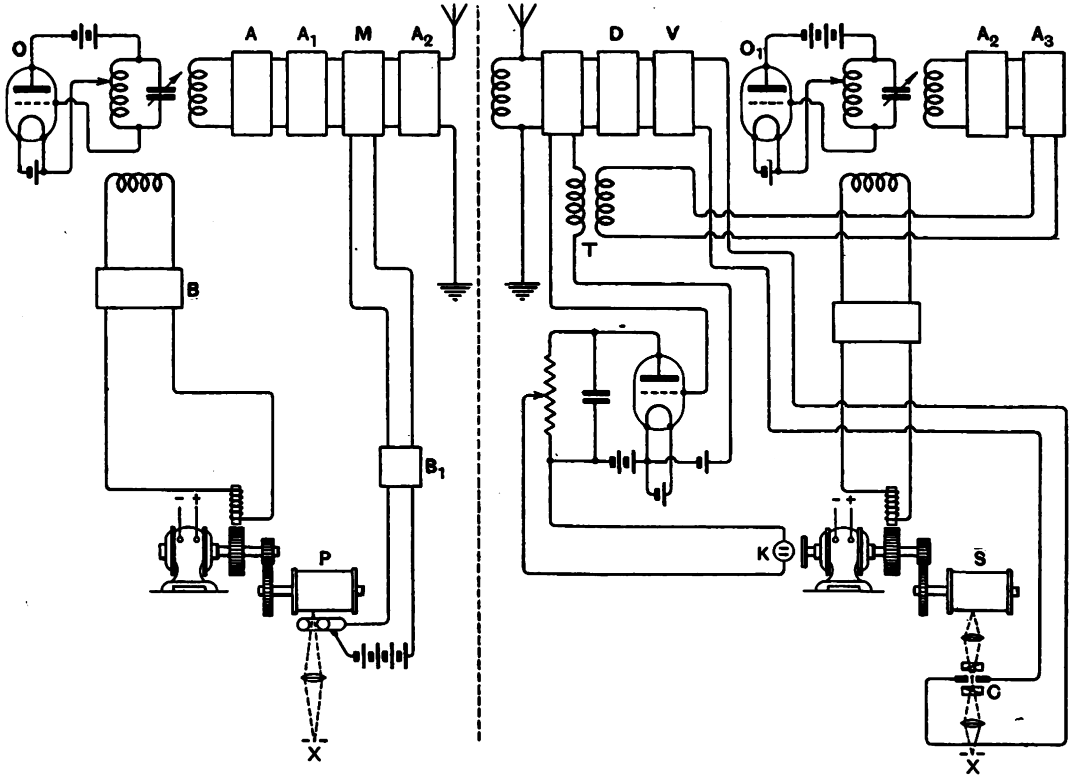


Patent issued to E. Giebe and A. Scheibe.

TELEVISION SYSTEMS.

(*Convention date* (*Germany*), *19th January*, 1926. *No.* 264816.)

In a system of television or picture-transmission, the picture-analysing device at the transmitting end is synchronised with the picture-building apparatus at the receiving end through the medium of the carrier-frequency on which the actual signalling elements are superimposed. For transmission a constant-frequency tube *O* generates a basic frequency of, say, 1,500 cycles per second. This is raised by harmonic selectors, *A*, A_1 to, say, 150,000 cycles.



Simultaneously the 1,500 cycle frequency is fed through an amplifier *B* to control a synchronous motor or La Cour wheel which drives the picture-transmitting drum *P*. The picture-signalling elements are first passed through an amplifier B_1 and are then used to modulate the 150,000 cycle frequency at *M*, the resulting complex wave being fed to the transmitting aerial.

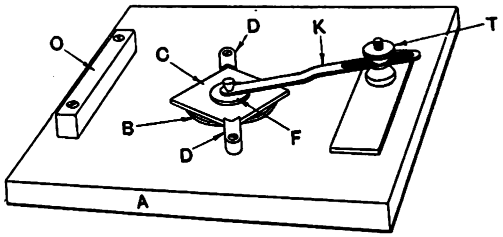
At the receiving station, shown on the right-hand side of the figure, a constant-frequency oscillator O_1 generates a similar basic frequency of 1,500 cycles, which instead of being multiplied a hundredfold as in transmission, is increased ninety-nine-fold by harmonic selectors A_2, A_3. This higher frequency is transferred at *T* and heterodynes with the incoming carrier wave. The resulting beat-note of 1,500 cycles is applied through an amplifier and a Kerr cell to exercise a stroboscopic control of the synchronous motor driving the picture-building drum *S*. Meanwhile the incoming signal components are detected at *D* and, after amplification at *V*, are applied to a light-control cell which is interposed between a source of light *X* and the drum *S*.

. Patent issued to A. Karolus.

QUARTZ OSCILLATORS.

(*Application date* 14*th September*, 1926. *No.* 279595.)

It is found that the output which can be controlled by a quartz crystal varies very considerably with the method of mounting the crystal. In particular, it depends (*a*) upon the asymmetrical position of the electrodes with respect to one another and of the crystal with respect to the electrodes (*b*) upon the shape and size of the electrodes relatively to the crystal, and to one another, and (*c*) upon the pressure of the electrodes against the crystal, or upon the air-gap left between the crystal and electrodes.



An adjustable mounting in which all the relevant factors can be controlled comprises a baseboard *a* of soft wood covered with velvet. The crystal *C* is mounted between a lower metal plate or electrode *B*, which is of approximately the same area as the crystal, and an upper electrode *F* which is considerably smaller. The latter is connected to a screw terminal *T* by a cranked strip *K* of metal capable of exerting a variable pressure.

When mounting the crystal, it is first suitably placed with respect to the bottom electrode *B*, and is then fixed in position by the side members. The upper electrode *F* is next adjusted as desired over the top surface of the crystal, and is then clamped by turning the screw terminal *T*. A ledge *O* is provided on the baseboard as shown, at approximately the same level as the top of the electrode *F*, so that an extra weight can be applied, if desired, by laying it across the ledge on to the upper electrode.

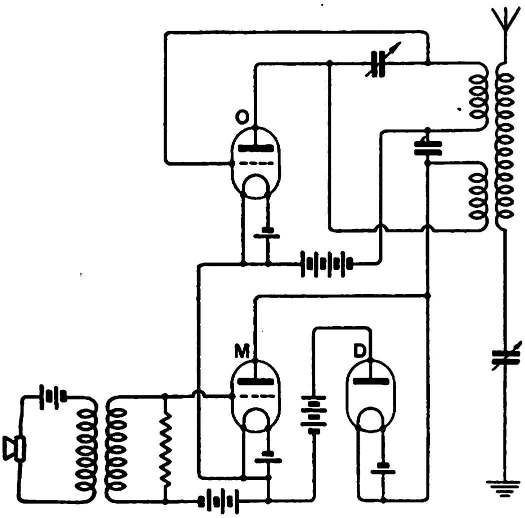
Patent issued to A. Hinderlich.

CHOKE MODULATORS.

(*Application date* 1*st July*, 1926. *No.* 279535.)

In the ordinary arrangement of choke control, it is found that the total space-current consumed by the oscillator and modular tubes is not maintained constant over the whole range of frequencies. At the lower frequencies, unduly large currents flow through the choke and thus tend to reduce the efficiency of transmission.

In order to overcome this defect a saturated *diode* or Fleming valve *D* is inserted in the common portion of the anode supply to the oscillator *O* and modulator *M*. Since the tube *D* will only permit the passage of a steady, or substantially invariable current, which represents the total anode consumption of the oscillator *O* and modulator *M*, any variation in the current passing through the latter must be accompanied by a corresponding change in the current flowing through the oscillator, thus ensuring a constant percentage modulation of the outgoing carrier wave.

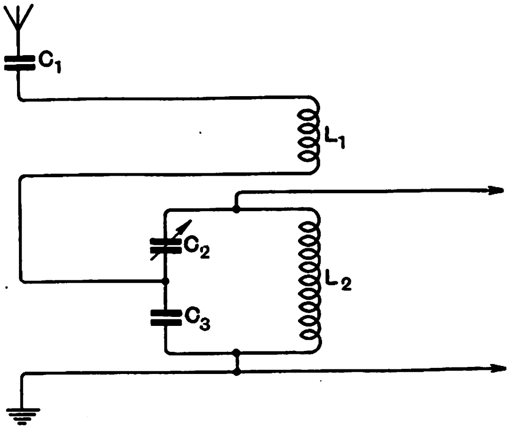


Patent issued to D. O'B. T. McAteer and W. A. Beatty.

A CONSTANT-COUPLING CIRCUIT.

(*Convention date* (*U.S.A.*), 8*th August*, 1925. *No.* 256644.)

The aerial circuit C_1, L_1, C_3 is coupled to the secondary circuit C_2, C_3, L_2 partly through a fixed condenser C_3 and partly across the coils L_1, L_2.



The system is tuned to the incoming signals by means of the variable condenser C_2. As the signal frequency rises, the reactance of the fixed condenser C_3 increases, and the energy-transfer across it falls off accordingly. Simultaneously the coupling across the coils L_1, L_2 increases, so that the two effects tend to counterbalance each other.

The total capacity reactance of the secondary circuit consists of the two condensers C_2, C_3, and the effective capacity coupling will therefore depend upon the relative value of these two components at any given moment. By suitably adjusting this value, the increase in inductive coupling can be made to compensate exactly for the decrease in capacity coupling, whereby the overall energy-transfer is maintained constant throughout a wide range of tuning.

Patent issued to S. Y. White.

LIGHT-SENSITIVE CELLS.

(*Application dates*, 30*th August*, 1926 *and* 12*th March*, 1927. *No.* 279937.)

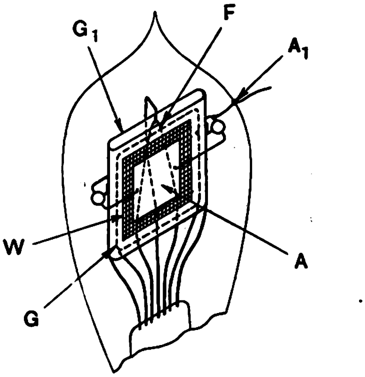
In order more effectively to control the electron emission inside a photo-electric cell, a third or control electrode has been inserted between the anode and cathode to function in the same manner as the grid in an ordinary three-electrode valve. It is found, however, that the presence of this grid or control introduces undesirable capacity coupling. The present invention therefore consists in the provision of a fourth electrode or screening grid, located between the grid and the anode, which does not impede the normal electron flow inside the cell, but which operates to prevent inter-electrode capacity coupling.

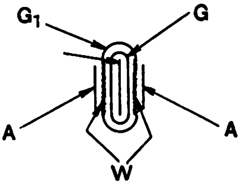
Patent issued to N. S. Smith and N. W. McLachlan.

SCREENED-GRID VALVES.

(*Application date, 22nd July,* 1926. *No.* 279171.)

As originally constructed the screened-grid valve necessitated a special type of holder, owing to the fact that the connections to the electrodes were made at both ends of the tube. According to the present invention the construction is modified in order to allow the valve to be mounted on a standard four-pin base. The arrangement of the electrodes is shown in elevation in the upper figure and in plan in the lower figure.





The anode lead A_1 is fused into the side of the glass tube, whilst the remaining connections are made through a four-pin base in the ordinary way. A hairpin filament *F* is surrounded by an open spiral control grid *G* which, in turn, is enclosed inside the outer or screening grid G_1. This is made of a flattened cylinder provided at each side with mesh-work windows *W*. The anode consists of a pair of plates *A* connected to the common lead A_1 and mounted close to each window.

Patent issued to H. J. Round.

RECTIFIERS.

(*Application date, 12th November,* 1926. *No.* 279259.)

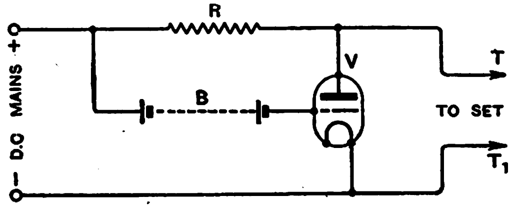
Silicon, either in solid form, or in combination with an aqueous electrolyte, such as an alkaline hydroxide, carbonate, etc., or sulphuric, nitric, or hydrochloric acid, is used as a rectifier for alternating current of the order supplied for domestic lighting. Its action in this respect is distinguished from its known use as a detector of radio-frequency currents. The rectifying electrode is preferably formed of solid silicon of comparatively large size, or a metal plate with a surface coating of silicon may be used. For dry-contact rectification a number of silicon plates in contact with silicon oxides or sulphides are employed.

Patent issued to L. P. Bensing.

D.C. SMOOTHING DEVICES.

(*Application date, 10th September,* 1926. *No.* 279214.)

In order to steady the voltage supplied by D.C. mains to the high-tension circuits of a valve receiver, an impedance *R* is inserted in series with one of the mains, and the anode-cathode circuits of one or more valves *V* are bridged across the mains between the impedance and the load. The grid of the valve *V* is connected through a battery *B* to the positive main as shown. Should the potential of the main supply rise, the resulting back E.M.F. across the impedance *R* throws the grid more positive, so that more current flows through the valve, and *vice versa*, thus maintaining a constant voltage across the terminals *T*, T_1. The correct value of the impedance *R* is determined by the mutual conductance of the valve *V*.

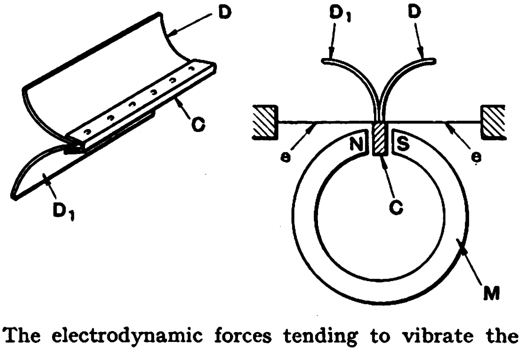


Patent issued to W. J. Brown and the Metropolitan Vickers Co.

LOUD-SPEAKERS

(*Convention date* (*Germany*), 15*th March,* 1926. *No.* 267564.)

In the folded or arched diaphragms of the type shown, the junction of the edges *D*, D_1 is enclosed by a metal rib *C* which is inserted in the narrowest possible gap between the poles of the magnet *M*.

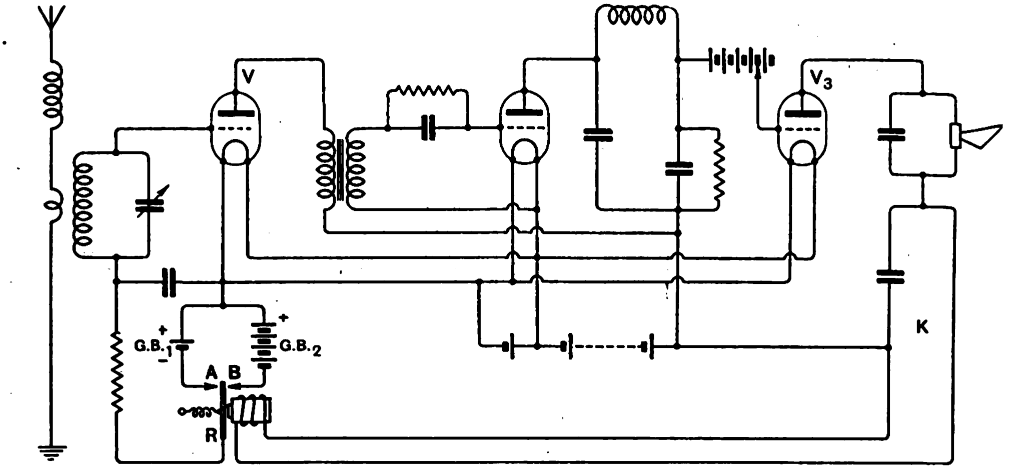


The electrodynamic forces tending to vibrate the diaphragm are thereby distributed along the conducting rib in a uniform fashion, so that rattling or chattering is avoided. The rib *C* may be supported laterally by elastic bands or threads.

Patent issued to the Siemens and Halske Co.

SIGNAL-STRENGTH CONTROL.

(*Convention date* (*France*) 13*th April*, 1926. *No.* 269554.)



Relates to an automatic method of gain-regulation with the object of compensating for fluctuations in signal strength due to various causes such as fading. The sensitivity of the first valve *V* is controlled by the provision of two alternative grid-biasing batteries G.B.$_1$ and G.B.$_2$, the application of one or the other of these being made dependent upon the strength of current flowing in the output of the last valve V_3.

For maximum sensitiveness the arm of the relay *R* will rest against the contact *A* so as to impose a small negative potential from G.B.$_1$ on the grid of valve *V*. Should the output from the amplifier V_3 grow too strong, or tend to blast, the current in a branch circuit *K* operates an electro-magnet to swing the arm *R* over into contact with *B*, thus placing a strong negative bias from the battery G.B.$_2$ on the grid of the input valve.

A hot-wire ammeter may be used to operate the arm *R* in place of the electro-magnet shown. This arrangement is particularly useful in regulating the output from a receiver intended for alternate distant and close-range reception.

Patent issued to H. J. M. R. de Bellescize.

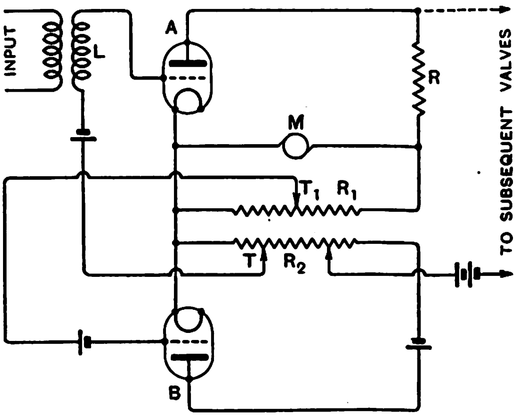
MAINS-SUPPLY UNITS.

(*Application date*, 19*th August*, 1926. *No.* 280645.)

In order to minimise the effect of fluctuations in the plate or filament supply to a valve set fed directly from the mains, an auxiliary valve is so arranged as to apply to the first valve a compensating grid voltage proportional to, and in phase with, the disturbance. As shown in the Figure, the plate voltage for the first valve *A* is taken from a dynamo *M*. The plate circuit is completed through two resistances, *R*, R_1.

The plate circuit of the auxiliary or compensating valve *B* is completed through a battery and series resistance R_2. A tapping *T* is taken from the resistance R_2, through a bias battery and the input coil *L* to the grid of the main valve *A*, whilst a similar tapping T_1 from the resistance R_1 goes to the grid of the valve *B*.

Should the voltage across the dynamo fall momentarily, then the voltage across the resistance R_1 falls also, and the grid voltage of the valve *B* becomes more negative, so that the plate current of that valve decreases. The voltage fall across the resistance R_2 is accordingly reduced, and the grid of the main valve *A* must therefore become less negative, whereupon its plate current increases, thus compensating for the initial falling-off in the power supply voltage.

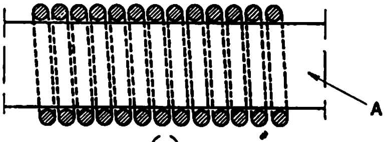


Patent issued to W. S. Smith and N. W. McLachlan.

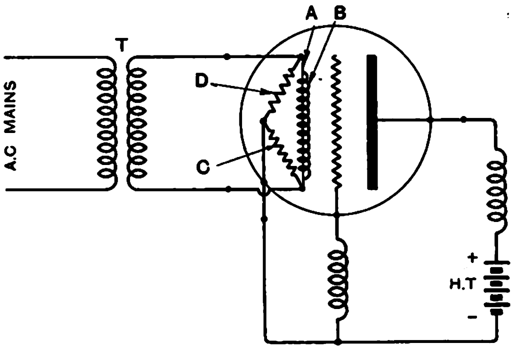
A.C. VALVE FILAMENTS.

(*Convention date* (*France*), 2*nd March*, 1926. *No.* 267078.)

In order to allow the use of A.C. current from the mains for energising valve filaments, with a minimum of "noise," the filament comprises a thick core *A* capable of taking a large heating-current, over which is wound a fine wire cathode *B* of thoriated tungsten or other material of high emitivity. The resistance of the wire *B* is so great relatively to that of the core *A* that practically no "mains" current passes through it.



(a)



(b)

To prevent electrostatic induction, two equal resistance elements *C, D* are mounted inside the bulb, in parallel with the spiral cathode, and the junction point is connected directly to earth. Or the mid-point of the cathode proper may be earthed; or a potentiometer tapping may be made to a resistance shunted across the secondary of the filament transformer *T*.

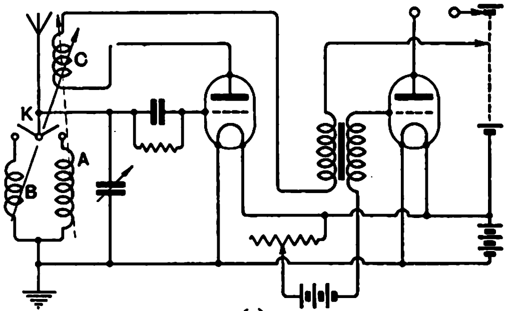
Patent issued to Société Luxor.

A FLEXIBLE TUNER.

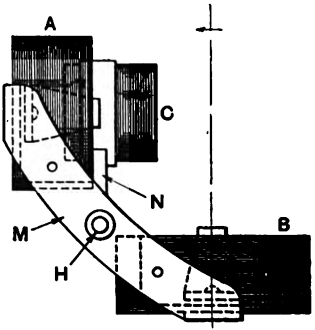
(*Convention date* (*U.S.A.*) *2nd December*, 1926. *No.* 279689.)

The circuit arrangement of a receiver designed to receive either short or long wave transmissions is shown in Fig. (a). Two aerial coils *A, B* are provided, together with a change-over switch *K*. In the left-hand position of the switch a short-wave coil *B* is brought into the aerial circuit, whilst in the right-hand position a coil *A* suitable for the long-wave Daventry transmission becomes effective. A common reaction coil *C* is made to serve for both settings.

The manner in which this is effected is shown in Fig. (b). Both the coils *A* and *B* are rigidly fixed to a common bracket *M*, being set at right angles to each other so as to minimise coupling. The common reaction coil is mounted on a link *N* pivoted at *H*, so that it can be swung from the position shown into close coupling with the lower coil *B*, when the wavelength switch *K* is changed over to a new setting.



(a)



(b)

Patent issued to Brandes Laboratories Inc.

ERRATA.

"A RADIO SIGNAL-INTENSITY RECORDER."—The record of reception on page 743 is reproduced half full size, and not full size as stated.

ABSTRACTS AND REFERENCES.—On page 765 of the December number, column 2, immediately below Fig. 2, the "horizontal antennæ described above" should read "described below," as the reference is to the Abstract appearing under the same heading of "Directional Wireless" on page 766.

"THE STABILITY OF THE TUNED-GRID, TUNED-PLATE H.F. AMPLIFIER."

PAGE 4.—Figs. 3 and 4 together constitute the component parts of Fig. 2.

PAGE 4.—Line 14: for "amplifiers" read "amplifier."

PAGE 8.—For section "9" read "9a."

PAGE 8.—Section 11: the references to "section 11" should be to "section 10."

PAGE 12.—Table II, for "166 $\mu\mu$F" read "160 $\mu\mu$F."

115

EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. V. MARCH, 1928. No. 54.

Editorial.

Potential Difference and Capacity in A.C. Problems.

THE capacity of any conductor is defined as the ratio of its charge to its potential under certain conditions as to other neighbouring conductors; the capacity of a condenser is usually defined as the ratio of its charge to the P.D. between its electrodes.

Both these definitions involve a definition of potential and a rigorous meaning can only be given to them in so far as a rigorous meaning can be given to the definition of potential. Now the P.D. between two points is defined as the work done in transferring unit quantity of electricity from one point to the other. Nothing is said about the path to be followed in making the transfer, because it is assumed that the work done is independent of the path. This assumption is justified in an electrostatic field or in the case of a steady direct current; in such cases the work done in transferring unit charge from one point to another is quite independent of the path followed. This follows from the fact that in such a field, where magnetic fields are either non-existent or unvarying, the resultant work done in moving an electric charge around any closed path, back to the point from which it started, is zero. In other words, the line integral of the electric force around any such closed path is zero. Hence so long as we are dealing with electrostatic problems or steady current problems, the definitions of potential and capacity are rigorously definite.

As soon as we try to apply these definitions to A.C. problems, however, we get into difficulties. A varying current produces a varying magnetic field, and in such a field the line integral of the electric force around a closed path is not necessarily zero, but is proportional to the rate of change of magnetic flux through the closed path. The result of this is that the work done in transferring unit charge from one point to another—which by definition is the P.D. between the two points—is no longer independent of the path followed by the unit charge. Strictly speaking, the term "Potential Difference" is not applicable to A.C. circuits; it is a term based upon conditions which do not hold in A.C. circuits, and defined in a way which leads to indefinite results when applied to them. This may come as a surprise to many readers, but it is true, and its realisation is of great importance to a proper understanding of the difficulties confronting one in attempts to apply low-frequency methods and formulæ to high-frequency problems. But surely—a reader will object—when it is stated that the P.D. between the terminals of an A.C. generator is 200 volts, the statement has a definite meaning. To a very high degree of approximation, yes, but rigorously, no, unless the definition of P.D. can be modified.

The reason for the lack of absolute definiteness can perhaps best be appreciated from a consideration of Fig. 1, which represents a portion of an overhead single phase transmission line. To measure the P.D. between the lines at the points *A* and *B*, an electrostatic voltmeter may be connected between the points. In the figure it is shown in three alternative positions, and in a D.C. circuit the reading on the voltmeter would be identically the same in each position. Very accurate observations would show, however, that in the A.C. case the voltmeter reads differently in the three positions, and the reason is obviously due to the E.M.F. induced in the voltmeter wires by the magnetic flux produced by the current in the transmission lines. An attempt to read the P.D. at a distant point on a voltmeter in the power station by means of pilot wires, as is done on D.C. systems, might lead to very wrong results when applied to an A.C. system, unless special precautions were taken. Some reader may say that the obvious thing to do is to connect the voltmeter between the two points by the most direct route. True, but our definition of Potential Difference will then have to be modified and defined as the work done in moving unit charge from one point to the other *by the most direct route.* This is good enough for most low-frequency cases, because the differences introduced by any reasonable departure from the most direct route, or by any difference of opinion as to which is the most direct route, are practically negligible.

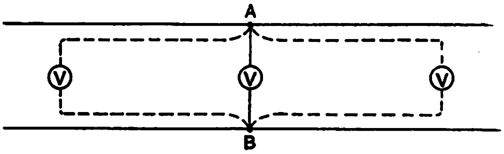


Fig. 1.

This is no longer true, however, when applied to radio frequency circuits and the higher the frequency the more indefinite becomes the meaning of the potential difference between any two points.

Fig. 2 represents a circuit in which some A.C. generator *G* is maintaining a high-frequency current. *AB* and *BC* represent inductive coils, and *CD* a piece of wire of negligible resistance. Three alternative positions are shown for a voltmeter connected across *A* and *C* with the object of measuring the P.D. between these two points. Similarly three positions are shown for a voltmeter across *C* and *D*. Which route one regards as the most direct in each case is a matter of taste. If the coils are very inductive the reading on the voltmeter across *AC* will vary very little with the position of the voltmeter; it will vary to some extent, however, and no rigorous definite value can be assigned to the P.D. In the case of the voltmeter across the points *C* and *D*, matters are much worse, since large variations in the reading are caused by the movements of the voltmeter, and the closer the voltmeter leads are brought to the most direct route—that is, lying alongside the wire—the nearer will the reading approach zero.

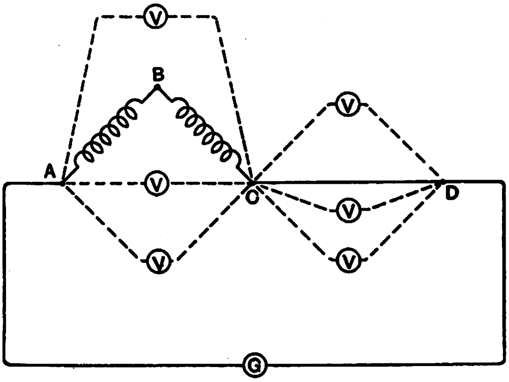


Fig. 2.

If Fig. 3(*a*) represents a single phase overhead transmission line on which the points *AB* are a mile distant from the points *CD*, then the fall of potential or the drop per mile is the difference between the P.D. across *AB* and that across *CD*. This would be determined by connecting a voltmeter across *AB* and another across *CD*, in each case by the most direct route. If, for the sake of convenience, however, one were to put the two voltmeters together somewhere midway between *A* and *C* and run long voltmeter wires to the four points, the route followed by the wires would be a matter of vital importance. This has nothing to do with any current taken by the voltmeters, and we may assume that electrostatic instruments of negligible capacity are employed.

Again, if one assumes that the drop per mile is equally divided between the two wires *AC* and *BD*, whatever that may really mean, we should expect a voltmeter across *AC* to read half the difference between the voltmeters across *AB* and *CD*, but this could only be managed by running the voltmeter leads along a certain route, and that hardly the most direct route.

Fig. 3(*b*) shows the correct route, and Fig. 3(*c*) shows a route which would give entirely different results. All these difficulties, which are non-existent in dealing with direct current, arise through the application of the idea of potential difference to cases to which it is, strictly speaking, inapplicable.

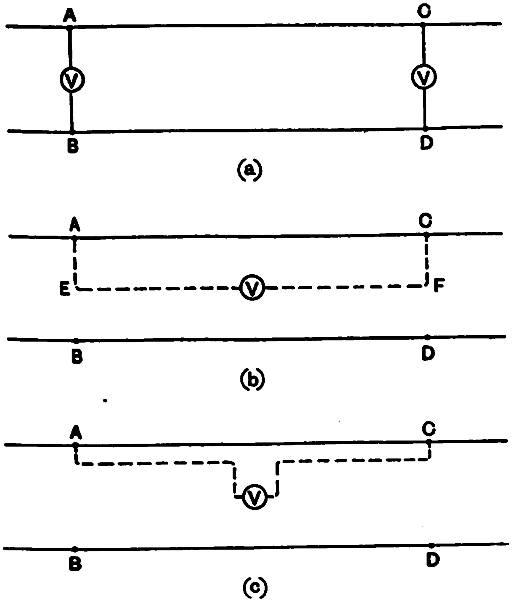


Fig. 3.

In the theory of A.C. transmission lines, one designates by *C* the capacity of the line per unit length. This is by definition the ratio of the charge per unit length to the P.D. between the wires. Is this to be determined under electrostatic conditions or under working conditions? We have seen that only under electrostatic or steady current conditions can a rigorous meaning be attached to the P.D. between the wires. Even then, however, the P.D. will depend not only on the charge on the unit length considered, but on the charge on the rest of the line, and therefore on its distribution along the line. The usual assumption made is that the line is infinitely long compared with the distance between the wires, and that the charge is uniformly distributed along it. In practice the length of the line is usually very great compared with the distance apart of the wires, and the charge per unit length changes very little over considerable lengths, so that these assumptions are justified. If we attempt to define the capacity under A.C. conditions we immediately meet the difficulty of defining the P.D. between the lines, when they are carrying an alternating current, and although we can get over the difficulty as indicated above by adding the words "by the most direct route" to the definition of P.D., we should not forget that we have thereby done something very different from what we did when we assumed that the line was infinitely long and uniformly charged; those were justifiable assumptions, but this is playing fast and loose with one of the fundamental definitions of electrical theory.

In our opinion it is better to avoid this difficulty by defining the capacity per unit length as that determined under electrostatic conditions from an assumed distribution of charge corresponding as closely as can be predicted to the distribution actually occurring in normal A.C. operation.

In Figs. 1 and 3(*a*) we agreed that in the presence of alternating currents we should take as the P.D. the work done in moving the unit charge from one point to the other over the most direct route, whereas in Fig. 3(*b*) we saw that to obtain a consistent result for the P.D. between the points *A* and *C* it was necessary to follow a path which could not be called the most direct. Is there perhaps not something common to both these cases which may throw light on the question as to the proper path to follow in every case? Yes. If the vector potential be found at every point, it will be noticed that the path followed in both cases lies entirely in planes at right angles to the direction of the vector potential or in planes of zero vector potential. For those not familiar with vector potential we may explain that just as a charge dq produces at a point at distance r a scalar potential dq/r, so an element of conductor of length dl carrying a current i produces at a point at distance r a vector potential $i.dl/r$ in a direction parallel to the current. Just as the total scalar potential at a point is the algebraic sum of all the component scalar potentials, so the total vector potential is the resultant of all the component vector potentials. In the case of the two parallel wires carrying currents in opposite directions, the vector potential will be necessarily parallel to the wires and will therefore have no component in planes normal to the wires; it will also be zero in the mid-plane all points of which are equidistant from the two wires. In Fig. 1 the voltmeter reading is unaffected by the path followed by the voltmeter leads so long as they remain in the plane through AB normal to the transmission line or in the midplane. Such a path is shown in Fig. 4, in which the voltmeter will read exactly the same as in the mid-position in Fig. 1.

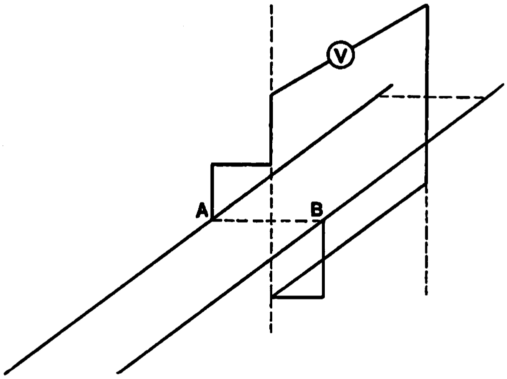


Fig. 4.

It will be seen that the path followed in Fig 3(*b*) conforms to this rule; the path can be as long and tortuous as one likes, the voltmeter reading will be unaffected so long as the paths from A to E and C to F remain in their normal planes, and that from E to F in the midplane.

This leads us to modify the definition of the P.D. between two points as the work done in moving unit charge from one point to the other, by adding the proviso that in the presence of varying currents or varying magnetic fields, the path followed should be either at right angles to the vector potential at every point or in planes of zero vector potential. This is not absolutely essential so long as the resultant line integral of the electric force due to the vector potentials is zero over the total path followed; that is to say the sum total of all the errors introduced by departing from the ideal path must be zero.

This rigorous definition replaces then our rough working rule of following the most direct route, which we found of very limited application.

By calculating the vector potential at every point of the circuit of Fig. 2 one could map out a path from C to D, normal at every point to the vector potential at that point, and then by calculation or measurement could determine the work done in moving unit charge along the path from C to D. This gives us what we must presumably regard as the P.D. between the two points.

The path—or paths, for there are an infinite number of them—gives the position of the voltmeter wires, in order that the instrument may correctly record the P.D. This path encircles just that part of the total magnetic flux which can be regarded as linked with the wire CD. We say advisedly "can be regarded as linked with the wire CD," for the whole procedure appears very arbitrary when applied to such a case; it is, however, a necessary corollary to the conception of a P.D. between the points C and D utilised partly in overcoming the ohmic resistance of the wire CD, and partly in overcoming a back *E.M.F* induced in the wire by a certain fraction of the total magnetic flux which links the circuit.

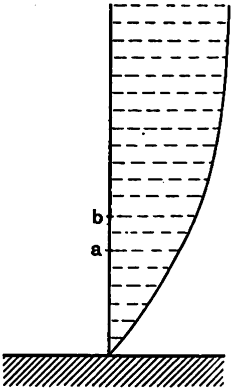


Fig. 5.

Since we assume that the path followed is such that the line integral of the electric force due to the vector potential is zero, the

P.D. so determined is due entirely to the distribution of electric charge around the circuit at the moment considered. It is the value which would be found whatever the path followed, if we imagine the current to cease, but the charges to remain unchanged, that is, it is the P.D. corresponding to a fictitious electrostatic case.

We now turn to an example of special radio interest. The transmitting aerial is often considered as an example of an A.C. transmission line and an attempt is made to apply the ordinary telephone transmission formulæ to it.

To do this it is necessary to give a value to the capacity per unit length of the aerial wire, and the question arises as to what meaning can be attached to the term in this special case. Let Fig. 5 represent a plain vertical transmitting aerial oscillating at its fundamental frequency, *i.e.*, with a wavelength a little more than four times its height. What do we mean by the capacity of the piece of wire *ab*, or rather, of this length of the equivalent transmission line? Certainly not the capacity of this piece of wire in the absence of the rest of the aerial.

There are several alternative electrostatic interpretations; for instance, if the aerial were disconnected from the earth and charged to unit potential the charge on the portion *ab* would be one measure of its capacity; again, if the wire is assumed to be charged uniformly its potential will vary from point to point, and that at *ab* could be used to calculate its capacity. In operation, however, the aerial is not uniformly charged, nor is it charged to the same potential, but its charge is distributed somewhat as indicated in Fig. 5.

Assuming such a distribution of charge to be possible electrostatically, the potential distribution along the aerial could be calculated, or, on the other hand, assuming the curve in Fig. 5 to represent, as it does approximately, the distribution of potential, the distribution of charge might possibly be determined; either of these purely electrostatic methods would give a result for the capacity of the element *ab*, but it must not be overlooked that the assumptions are far removed from any possible electrostatic condition. The only way in which the aerial could be given such a charge would be by dividing it up into a number of short pieces of wire each insulated from the neighbouring pieces.

Any attempt to define the capacity of the element *ab* under working conditions leads one into great difficulties. One may simplify the problem by assuming a plane earth of infinite conductivity and considering the combination of the aerial and its image as the two wires of a transmission line with the transmitting station at the earth's surface. The P.D. between *a* and a^1 will differ from that between *b* and b^1, the difference being the drop along the length *ab* of the combined line, and half the difference the drop along the length *ab* of the aerial wire. This sounds very simple until one tries to give a definite meaning to the P.D. The work done in moving a unit charge from *a* to a^1 will differ enormously, depending upon the path followed, due to the rapidly changing magnetic field in the surrounding space. A further difficulty meets us in this case which we have not yet mentioned, and that is due to the fact that the force on the unit charge at any moment is not that calculated from the charges and currents in the aerial at that moment, but allowance must be made for the time taken for the electromagnetic effects to travel from the various parts of the aerial to the point where the unit charge is situated at the moment. This effect, which enormously complicates the problem, is negligible in the cases previously considered, but is by no means negligible in the present case.

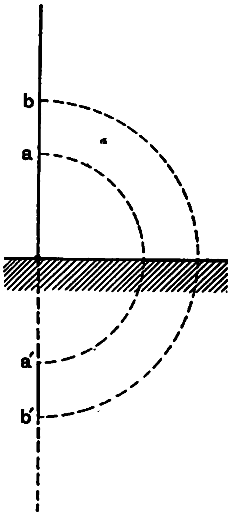


Fig. 6.

After much consideration we have come to the conclusion that it is advisable not to attempt any A.C. definition of the capacity per unit length of the aerial, in the application of the transmission line formulæ, but to calculate the electrostatic capacity on the assumption of a distribution of charge such as shown in Fig. 5, or other distribution, depending on the wavelength employed.

When the capacity per unit length is thus determined for all points along the aerial, the inductance per unit length follows at once from the formula

$$v = \frac{1}{\sqrt{CL}}$$

where v is the velocity of light.

From the assumed distribution of charge the distribution of current can be determined, and from this and the distribution of inductance the voltage along the aerial can be determined by ordinary A.C. methods. This should agree with the voltage distribution calculated electrostatically from the assumed charge. If it does not, the assumed distribution of charge needs correction and the calculation must be repeated.

We have then replaced the actual aerial by a system of inductances and condensers, as shown in Fig. 7, in which the magnetic fields are confined within the inductance coils.

Unfortunately, the magnitude of the condensers and inductances depends on the electrical conditions of the system.

This may not appear to some a very satisfactory method, but it has the important advantage that the capacities, inductances, and potentials involved are all defined in a perfectly definite manner.

The result can only be regarded as an approximation, since the method uses simple devices to solve a very complex problem.

The field of the electrostatically charged aerial woud extend indefinitely into space, whereas in operation the field travels outwards with the velocity of light, and at the moment of maximum charge is confined, so far as it emanates from that charge, to a limited space around the aerial. No method which ignores the finite velocity of the field from the aerial into space can be regarded as more than a rough approximation to the actual problem.

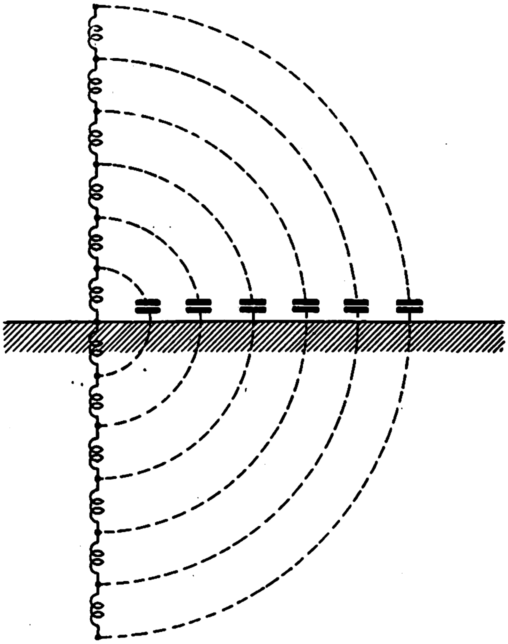


Fig. 7.

G. W. O. H.

Generalised Theory of Antennæ.

By Raymond M. Wilmotte, B.A.

Definitions.

IN the issue of last November there is published a very interesting paper on antennæ by F. M. Colebrook. It was after discussing with him the problems which he had set himself that I tackled them also, freeing them as far as possible from the assumptions of which both he and Moullin* were conscious. The few experiments that I have made justify the theoretical conclusions. In this respect I hope to have completed, or at any rate partly completed, the gaps which Colebrook noted at the conclusion of his paper.

The general problem can be stated as follows: It is required to find how far the effective constants of antennæ used as transmitters and receivers are equal. By constants is meant the reactance, ohmic resistance, radiation resistance, effective height, etc. All these constants need careful definition.

In all forms of electrical measurements it is necessary to have a very clear idea of what is being measured; sometimes the meaning of the quantity being measured is obvious and its value can safely be used for other arrangements of the apparatus or conditions. Very often, however, this is far from being the case. When dealing with antennæ, the exact meaning of a measurement is not usually immediately clear. It becomes necessary, therefore, to define the terms used with considerable care.

In ordinary electrical circuits, the current is usually constant throughout, or very nearly so; this is not the case for antennæ. The circuit appears remarkably simple, being in the main a number of straight lengths of uniform wire. The difficulty arises owing to the fact that the current is not constant, but is continually varying from one end of the antenna to the other.

This being so, the results of any measurement will depend on the position on the antenna of the apparatus used in making the measurement. That is why the word "effective" was used in connection with the constants of the antenna. It may be generally assumed, unless otherwise stated, that the point at which measurements are made is at the foot, between the antenna and the earth or counterpoise. The values obtained are then stated as though they applied to a simple circuit, in which the current was constant throughout, and equal to the current at the point of measurement; such values are usually called "effective" values. Thus, if the power dissipated in an antenna were found to be W and the current at the base I, the effective resistance would be given as W/I^2. The same applies for reactance, but in this case there is a further complication, since the reactance of a simple circuit can be made to vary with frequency by suitably adjusting the relation between the inductance and the capacity. The "effective" inductance and "effective" capacity are, therefore, chosen so that the variation of reactance with frequency in the immediate neighbourhood of the frequency used is the same for the equivalent simple circuit and the antenna. It may be of interest to some readers to consider this more fully, and in Appendix I a more detailed consideration is given to this question.

Returning now to the papers of Colebrook and Moullin, we must investigate what were the assumptions made therein. They are quite straightforward and were stated by the authors themselves. They assumed that an antenna behaved as though it had uniformly distributed constants; that is, that the resistance, capacity and inductance were the same per unit length at all points of the antenna. Both Colebrook and Moullin supposed, rightly as I now believe, that in simple antennæ the deviation from this was likely to be small, except perhaps in certain very localised parts of the antenna, such as near the earth end. The assumption cannot, however, be expected to hold for complicated constructions of antennæ.

The first question is: What is meant by capacity and inductance per unit length? The answer to this question is by no means obvious. We are now dealing with alternating currents; let us, therefore, consider the meaning of these terms from the alternating current point of view only, without any consideration for the present of their electrostatic meaning.

---

* "On the Currents induced in a Wireless Telegraph Receiving Antenna," by E. B. Moullin, *Proc. Camb. Phil. Soc.*, Vol. 22, pp. 567–578, 1925.

Consider an apparatus A at a potential v (Fig. 1). Let it have a capacity C to earth, then the current i_1 entering it will be different from the current i_2 leaving it. Using symbolic vector representation, this difference is given by

$$i_1 - i_2 = jvC\omega$$

where $\omega/2\pi$ is the frequency and $j = \sqrt{-1}$.

Hence, as far as alternating currents and potentials are concerned, a capacity is characterised by a change in the current. If the apparatus consists of a unit length of wire, then the admittance of the capacity C will be the ratio between the difference in the currents entering it and the potential of the wire. To put this into more mathematical language, the capacity per unit length is given by

$$jC\omega = -\frac{di/dx}{v} \quad \cdots \quad \cdots \quad (1)$$

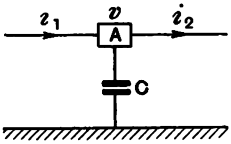


Fig. 1.—*Effect of capacity to earth explaining the meaning of capacity per unit length.*

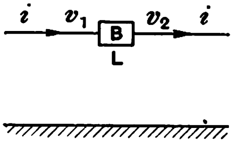


Fig. 2.—*Effect of self-inductance explaining the meaning of self-inductance per unit length.*

From this we can see that the greater the capacity per unit length, the greater the rate of change of current along the wire at the point considered.

With exactly similar reasoning, we can find the meaning of self-inductance per unit length. Suppose the apparatus B (Fig. 2) has a self-inductance L and no capacity. There will be a difference of potential between one end and the other of the apparatus, and this difference is given by

$$v_1 - v_2 = jiL\omega,$$

where i is the current through the apparatus.

A self-inductance is therefore characterised by a change in potential. If the apparatus consists of a unit length of wire, then the reactance of the self-inductance will be the ratio between the difference of potential across it and the current flowing through the wire. Mathematically, this can be written

$$jL\omega = -\frac{dv/dx}{i} \quad \cdots \quad \cdots \quad (2)$$

This shows that the greater the self-inductance per unit length, the greater the rate of change of potential along the wire at the point considered.

It will be noticed that in the above definitions resistances have been neglected. This has been done purposely in order not to confuse the issue. If there is a resistance from the element of length considered to earth, it should appear on the left-hand side of equation (1). Its effect can, however, be differentiated from the rate of change of the current due to the capacity, since the latter effect is in quadrature to the former. The same applies to the resistance in the element itself, which should appear in the left-hand side of equation (2).

This, however, is not the whole story. In equations (1) and (2) there are two terms whose meaning have been tacitly assumed, namely, the conduction current i and the potential v. The instantaneous conduction current is not difficult to define as the rate of flow of electricity, but the potential is not so simple.

In electrostatics, the potential at a point is defined as the work done against the electric forces in the medium in bringing a unit electric charge from infinity up to the point considered, and it is found that this is a circuital function, that is, the work done is independent of the path chosen. When, however, there are alternating currents (or currents varying with time in any manner), the electric forces in the medium are no longer only dependent on the distribution of charge, and the work done will depend on the path chosen; it is, therefore, necessary to seek a variation on the electrostatic definition of potential to fit the case when alternating currents are present.

The electric forces in a medium can be considered as the sum of two terms, one due to the distribution of charges and the other due to the distribution of the alternating currents.* It is only the work done against the latter that depends on the path taken; it is, therefore, convenient to define potential as the work done in bringing a unit charge from infinity up to the point considered against the electric forces due to the distribution of charge only.

Neglecting for simplicity the effects of resistance, let us suppose that we know the value of the rate of change of current and potential at any given point as well as the actual value of the current and potential. From equations (1) and (2) we can calculate the value of the "effective" capacity and self-inductance at that point. Consequently, any distribution of current and potential along an antenna will correspond to a certain definite distribution of capacity and self-inductance per unit length. (Any variation in the phase of the current or potential will correspond to resistances.)

The meaning of self-inductance and capacity per unit length should now be clear. This meaning does not necessarily have any relation to the meaning of the terms used in electrostatics, and what this relation is we shall now consider. These definitions may appear to be very artificial and the terms do not lend themselves to our minds for pictorial representation. If, however, their conception is useful, it is sufficient reason for retaining them.

Unfortunately, however, the solution of equations (1) and (2), whatever distribution of capacity and self-inductance per unit length is chosen, will give a result for both the current and the potential distribution, which will depend on the frequency. The values of the constants per unit length cannot, therefore, be expected to be the same for the electrostatic and the alternating current cases. By how much they differ is the next question to be investigated.

If we consider any element of a conductor, the reason, why the conduction current entering it is different to the conduction current leaving it, is that there is a component of the electric force which is normal to the surface of the element in contact with the dielectric. This component produces what is known as a displacement current and this is equal to the difference between the conduction current entering and leaving the element of the conductor under consideration. Moreover, if this normal component of the electric force were the same in the alternating as in the electrostatic case, the capacity per unit length would also be the same in the two cases.

In the case of an antenna, where the conductor consists of very long thin wires, the electric force due to the alternating currents alone (not the charges) will be mainly parallel to the wires; those components that are normal to the wires will be produced by currents flowing in directions also normal to the wires. It is true that such components may not be negligible, but at points not in the very immediate neighbourhood of bends, since the wire is comparatively thin, the normal electric force due to the conduction current in the direction from the dielectric to the conductor will be negligibly different from that from the conductor to the dielectric. The result is zero and it can be taken that the conduction current produces a negligible displacement current from the surface of the conductor. (This is not true in the neighbourhood of bends, but the effect will be very local.) We can therefore assume that the displacement current from the surface of the conductor is due to the distribution of charge only. There remain two reasons why the capacity per unit length may differ appreciably in the alternating and electrostatic cases. The first is that the reaction of one part of the system of conductors on another does not take place instantaneously, but with the velocity of light, and the second that the distribution of charge is different in the two cases. The first of these reasons will only become of importance at extremely high frequencies as it will only apply to those parts that are at an appreciable fraction of a wavelength away

---

* It will be evident that an alternating current distribution produces a distribution of charge. Thus, if a current having an instantaneous value i enters an element of length δx and a current $i + \delta i$ leaves it, the charge per unit length δq accumulated in the time δt is given by

$$\delta q = \delta i . \delta t / \delta x .$$

If, now, the current and charge per unit length vary sinusoidally with respect to time and have maximum values I and Q respectively, we can write in vector notation

$$Q = -\frac{1}{j\omega}\frac{dI}{dx} \quad \ldots \quad \ldots \quad (3)$$

From this equation the charge distribution can be calculated from the current distribution.

from the point considered. The second reason can be discounted only if the distribution of charge in the neighbourhood of the point considered is very nearly the same in the two cases. (It will be noted that it is the distribution and not necessarily the actual value of the charge that must be the same.) This again will hold except at extremely high frequencies. We can assume, therefore, that the capacity per unit length is not equal to but is approximately that measured electrostatically for all cases except at such high frequencies as are not to be encountered even in radio.

Turning our attention to the self-induction per unit length, we know that the difference between the electric force due to the distribution of charge and that due to the distribution of alternating current is equal to the resistance drop *Ri*. Since the difference of potential has been defined as due to the distribution of charge only, and since for simplicity we are neglecting the effect of resistance, we deduce that the difference of potential along a conductor is due to the electric forces (resolved along the conductor) due to the conduction currents. That is, the potential difference between two points on a conductor is equal to the work done by a unit charge against the electric force due to the conduction currents alone when that unit charge is moved from one point to the other (neglecting the effect of resistance). According to this the self-inductance per unit length will depend only on the distribution of the conduction currents and will be independent of frequency so long as the distribution of current in the neighbourhood of any element considered is sensibly the same at all frequencies. As in the case of charges, this will be approximately so except at extremely high frequencies.

We conclude, therefore, that the self-inductance and capacity per unit length have nearly the same distribution irrespective of the frequency for all practical cases. Moreover, in all cases an antenna, by suitably choosing the distribution of its constants per unit length, can be exactly represented by a system having self-inductances and capacities per unit length as defined by equations (1) and (2), although these self-inductances and capacities will vary slightly with frequency.

It is of interest to note in passing that the above arguments apply to the ordinary transmission line theory, but in this case the difference between the distribution of the constants in the electrostatic and alternating cases is even closer than in the case of an antenna. The reason for this is that not only is the frequency very much lower, but also the return circuit is very close to the outgoing wire and the two shield each other from the effects of the more distant portions of the line.

Distribution of the Constants in a Simple Antenna.

We shall now consider why the distribution of capacity and self-inductance per unit length cannot be considered rigorously as constant even in a simple antenna consisting of a straight vertical wire.

There are several reasons for this; the first will be obvious from the explanation that has been given in the previous paragraph. If the wire were infinitely long, its static charge per unit length would, from symmetry, be constant, so that its capacity per unit length would also be constant. When the frequency is high, however, the capacity per unit length will no longer be rigorously the same as the electrostatic capacity; moreover, since the distribution of potential is slightly different with respect to different elements of length, the capacity per unit length will also vary along the wire.

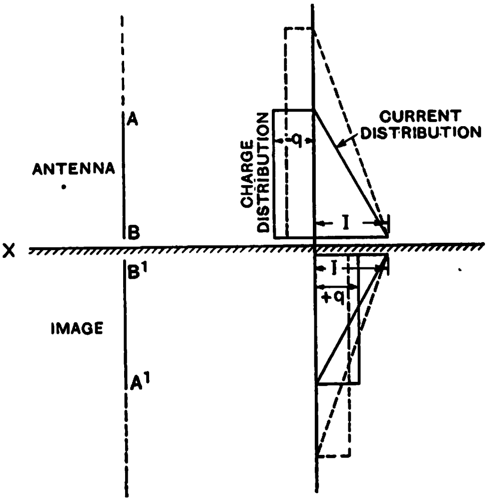


Fig. 3.—*Current and charge distribution of a simple antenna.*

The second reason is that even the electrostatic capacity is not constant per unit length when the length of wire is finite.

Let AB be the antenna (Fig. 3). Let it be given an alternating charge of R.M.S. value $-q$ per unit length as shown. This, from equation (3), is equivalent to an alternating current distribution uniformly decreasing from the value $+I$ at the bottom end B down to zero at the end A. If the earth XY is perfectly conducting, it will be an equipotential surface of zero potential. It is therefore possible to replace the earth by a charge distribution $+q$ per unit length from B' to A', where $A'B'$ is the exact image of AB in the earth. It only means that the charges induced in the earth by AB are equivalent to the charges on $A'B'$. This representation is a very convenient mathematical dodge known as the "Theory of Images."

The theory of images can be applied to the alternating current in an antenna, for the charge distribution in $A'B'$ corresponds to a current distribution which decreases uniformly from $+I$ at B' to zero at A'. That is, the field and potentials due to the eddy currents in the earth are exactly equal to those induced by the current in $A'B'$.

Let us first consider the end B and find whether the electrostatic capacity is large or small. The effect of the image in the earth is to induce a more positive potential near the end B than near the end A, and this potential will vary rapidly as the end B is approached. In order to keep the potential constant over the whole antenna (as it would be, if the capacity were measured electrostatically) the charge near the end B must be made more negative. This is equivalent to an increase in the rate of change of current and, by definition, to an increase in the capacity per unit length. Hence, near the bottom end B the capacity per unit length is greater than near the centre for low frequencies.

This result may appear obvious, but it gives us the clue for finding the effect near the top end A. Suppose the antenna were continued upwards as shown dotted, the potential at A would be unaffected by the end effects, so that the capacity per unit length would be the same as in the centre. Now, this added portion is inducing a greater negative potential at A than at B. If, therefore, this portion is removed, in order to retain uniform potential, the charge at A must be made more negative, which, as before, is equivalent to an increase in the capacity per unit length.

The arguments used for both ends are essentially similar. At the end A a negative charge is removed, while at the end B this charge is turned into a positive one. The capacity at B will, therefore, be greater than at A. Qualitatively, therefore, the distribution of current and capacity per unit length will be as shown in Fig. 4.

From this argument it will have become evident that the distribution of capacity is not only dependent on the geometrical shape of the antenna, but also on the frequency.

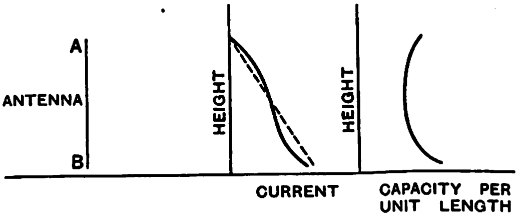


Fig. 4.—*Current and capacity distribution in a simple antenna at low frequencies deduced qualitatively.*

It would not be difficult to obtain similar conclusions with regard to the distribution of self-inductance, but as the argument is essentially similar to that applied to the distribution of capacity it will not be given.

The Effective Constants of Receiving and Transmitting Antennæ.

These considerations will have shown the importance of obtaining theoretical results which are independent of assumptions regarding the distribution of capacity and self-inductance per unit length along an antenna.

The mathematics is straightforward, but for convenience it is put in Appendix II.

The only assumption made in comparing the constants of an antenna used for transmission and reception is that the distribution of capacity, self-inductance and resistance is the same in both cases. It is therefore necessary to inquire how far such an assumption is justified.

The essential difference as far as the antenna is concerned between reception and transmission is that the distribution of E.M.F. is different in the two cases. One could expect that the effective constants of a complicated circuit (to which an antenna corresponds) measured at any point might depend on the manner in which the E.M.F. is applied. In Appendix II this is proved not to be so, but only so long as the distribution of E.M.F. does not affect the distribution per unit length of capacity, self-inductance and resistance along the circuit. In an antenna the distribution of the constants per unit length could hardly be expected to be a sharp function of the current distribution; that is, unless the current distribution were totally altered by the change in E.M.F. distribution, the distribution of the constants along the antenna would not be expected to vary very much. (For it is only the variation in the current distribution in the immediate neighbourhood of any point under consideration which will cause an appreciable variation in the constants per unit length at that point.)

Now, since in practice the resistance of any elementary part of an antenna is small compared to the reactance, the potential differences between the various parts will be produced mainly by the reactance, and only to a very small extent by the applied E.M.F., when the antenna circuit is tuned, for the current is then comparatively large. It is not to be expected, therefore, that the current distribution will greatly depend on the distribution of the applied E.M.F., while the distribution of capacity and self-inductance will depend on the E.M.F. distribution to very much smaller extent. The assumption made leaves only second order effects out of consideration, and is a very much closer approximation to the assumption made by Colebrook and Moullin that the constants are uniformly distributed.

In the analysis given in Appendix II, the general case of an antenna having an E.M.F. V applied at the foot as well as a distributed E.M.F. along it is considered. By putting $V = 0$ we obtain the case of a receiving antenna, while, if the E.M.F. distributed along it is put equal to zero, the antenna becomes a transmitting antenna.

If i_0 is the current at the foot of the antenna and there is an impedance Z between the foot of the antenna and the earth, equation (9) of Appendix II shows that we can write

$$i_0(Z + Z_0) = V + E_0,$$

in which Z_0 is independent of the applied E.M.F.'s and E_0 is independent of the impedance Z.

The antenna circuit can therefore be represented by a circuit such as that shown in Fig. 5. The "effective" impedance of the antenna Z_0 is independent of the applied E.M.F.'s and is, therefore, the same for transmission as for reception. E_0 will be the "effective" E.M.F. of the applied field.

Incidentally this result applies equally well to any form of transmission line.

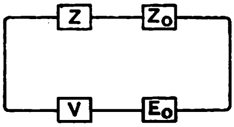


Fig. 5.—*Equivalent circuit of an antenna circuit.*

The next problem is the comparison of the effective height of the same antenna transmitting and receiving.

The definition of the effective height of an antenna is by no means simple. On Hertz's simple doublet theory, the field strength at any point at a large distance from the antenna is proportional to the strength of the doublet, and inversely proportional to the distance.

Now, an excited antenna can be considered as a series of doublets, and the field strength at any point will be proportional to the sum of the radiations due to the doublets, taking into account the relative phases at which these radiations arrive at the point considered. When the antenna is small compared with the wavelength, the radiations from the various parts of it will arrive substantially in phase,* but when it is comparable or large compared with the wavelength, that will not be so. In this latter case directive effects occur, so that even at large distances from the antenna the radiation will not be the same in all directions; moreover, these directional effects are not necessarily confined to the horizontal plane. Nevertheless, the effective height must bear some relation to the signal strength. There are further difficulties that enter this question which arise from the absorption of the electromagnetic radiation by the earth, due to its resistivity and also the effect of the radiation reflected from the conducting layers of the atmosphere.

---

* This is not rigorously correct, but few exceptions to this rule are met with in practice.

The most convenient method of representing these effects is to use a separate factor for each. Thus, there would be a factor for the law of propagation of the waves, another factor for the absorption of the ground and intervening objects, another factor for the directivity, and, finally, a factor for the distribution of current and the shape of the antenna. It is this last factor which is called the " Effective Height."

Unfortunately, most of these factors interact to a greater or less degree on one another, especially that of directivity and of effective height, so that the latter has no very definite meaning unless referred to the field strength of the radiation at some definite point. Such a point could conveniently be on the surface of the earth in the direction of maximum radiation.

Over a perfectly conducting plane earth, the image in the earth is the exact reproduction of the antenna itself, and the sum of the radiations on the earth's surface due to the series of doublets forming the antenna will be proportional to the integral of the current over the antenna resolved in the vertical plane, making a suitable allowance for the phase difference of the radiations from the various parts. This difference in phase will only occur if the antenna stretches in a horizontal plane over a distance comparable with the wavelength, as in a beam station, for example. The general formula for the effective height of a transmitting antenna is given by equation (14) of Appendix II.

It may be noticed that if the earth is not perfectly conducting it will not be rigorously an equipotential surface, and a correction should be applied. However, until more is known on this point we must be content with the above definition.

The effective height of a receiving antenna is apparently more easily defined. If an electromagnetic wave having a uniform electric intensity E approaches the antenna, a current I is obtained at the foot of the antenna. If an E.M.F. V applied at the foot were alone able to produce the same current I, we obtain at once for the definition of the effective height R of a receiving antenna

$$R = V/E.$$

It is necessary to assume a uniform electric field, otherwise the definition becomes meaningless. The value of R is given by equation (16) of Appendix II and comes out to be identical with the value found for the effective height of a transmitting antenna. We thus obtain the following proposition :—

" If the distribution of the constants along an antenna is unaffected by the applied E.M.F.'s, the effective height is the same for transmission as for reception."

The final point for theoretical consideration is that of radiation resistance.

This is proportional to the total energy radiated, which energy, for a given current and radiation polar diagram, will depend largely on the effective height of the antenna defined as for a transmitting antenna. That is, if this effective height is large, so will the radiation resistance be expected to be large.

For a transmitting antenna this effective height is independent of the impedance between the foot of the antenna and earth. [See equation (14) of Appendix II.] For a receiving antenna, however, the effective height due to the re-radiation does depend on this impedance [equation (18) of Appendix II]. The radiation resistance will not, therefore, be the same for transmission and reception.

In the special case considered at the end of Appendix II of an antenna having uniformly distributed constants, the values of the effective height are given for both transmission and reception [expressions (19) and (20) of Appendix II]. In the case of reception this effective height is a measure, not of the effect of the received signal, but of the strength of the re-radiated field. When the antenna is tuned it will be seen that the value of the effective height of the antenna considered as a transmitter and, therefore, the radiation resistance, is smaller for transmission than for reception, the difference depending on the value of Z of the impedance between the foot of the antenna and earth.

In fact, when Z is infinite, the difference in the radiation resistance is also infinite. The physical interpretation of this is easily found. If Z is infinite, the current I at the foot of the antenna will be zero. Thus, in the case of transmission there will be no current whatever in the antenna, while, owing to capacity and inductance effects, some current will flow on reception; this current will produce a re-radiated field. On reception, therefore, some power is re-radiated, although the current at the base may be zero. This will evidently give rise to an infinite radiation resistance, since the measurements normally refer to the effective value at the foot of the antenna.

Experimental Verification.

In order to test the theoretical conclusions outlined above, the following experiments were carried out.

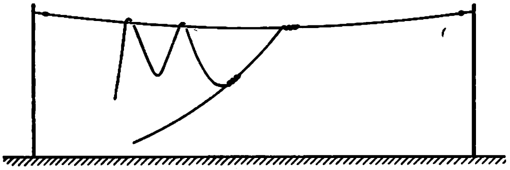


Fig. 6.—*Shape of antenna used in experiments.*

To ensure that the antenna under measurement did not possess uniformly distributed inductance, capacity and resistance, loops of wire were added to it until its shape was as shown in Fig. 6. A counterpoise earth was used.

The measurements were carried out by inserting the antenna in a circuit (Fig. 7) consisting of an inductance *L*, a condenser *C* and an ammeter. The circuit was measured with and without the antenna, keeping the counterpoise permanently connected to the point *A* during all the measurements.

The resistance was measured by the variation of reactance method by varying a small accurately calibrated condenser in parallel with the condenser *C*.

For transmission a small power set inducing directly into the coil *L* was used, while another antenna excited by a larger power set was used for testing the antenna as a receiver. The two antennæ were about fifty yards apart. A large army hut running the whole length of the antenna under measurement and within a few feet of it between the receiving and transmitting antennæ, ensured that the field at the receiving antenna was not uniform.

It was ascertained that the direct induction from the transmitting antenna into the coil of the measuring circuit was negligibly small. The two power sets were adjusted to the same frequency by means of the same wavemeter, without alteration of the setting, so as to eliminate small errors due to frequency adjustments.

Since the differences were only to be expected at high frequencies, as short a wave length as was conveniently possible (compatible with accurate measurement) was used. Table I gives the results of the measurements. The figures for the reactance and resistance refer to the antenna alone, without the rest of the circuit. They were obtained by subtracting the values for the circuit with and without the antenna.

The last result at a wavelength of 114 metres is interesting, for it represents the antenna beginning to act as a rejector circuit. Owing to its shape, the down-coming lead is for a long portion of its length quite close to the earth screen, thus acting as a large capacity. The rest of the antenna acts as a positive impedance at that frequency, so that a rejector circuit is formed. This is the reason for the sudden rise in the value of the resistance. This condition could be altered by changing the shape of the lead-in wire. This was done and, though no very accurate measurements were made, the effective resistance decreased to the value of the order of 15 ohms.

TABLE I.

Wavelength in Metres.	Reception.			Transmission.		
	Setting of Condenser *C*.	Reactance in Ohms.	Resistance in Ohms.	Setting of Condenser *C*.	Reactance in Ohms.	Resistance in Ohms.
208.5	119.8	−297.0	4.2	120	−297.0	4.2
140.0	283.0	− 74.0	5.0	283	− 74.0	4.9
127.0	186.0	− 7.8	7.2	186	− 7.8	7.0
114.0	215.0	+ 89.0	64.0	215	+ 89.0	70.0

From the table we see that the natural wavelength of the antenna is slightly below 127 metres. This, incidentally, is a very accurate method of finding the natural wavelength of an antenna without having instruments liable to alter the value searched for. The process consists in exciting the circuit by inducing an E.M.F. from a local source into the coil L (Fig. 7). The reading C_1 of the condenser is taken when the circuit is tuned to the frequency of the source, as seen by the deflection of the ammeter, with the switch S connected to A, so that the antenna is not in the circuit. The switch S is now connected to B and the new capacity C_2, for which the circuit is now tuned, is noted.

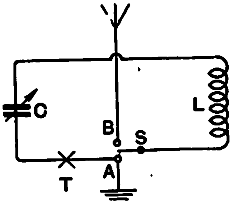


Fig. 7.—*Circuit for measuring the natural frequency of an antenna.*

Obviously, if $C_1=C_2$, *i.e.*, when there is no change in the tuning conditions produced by the insertion of the antenna in the circuit, the antenna must be acting as a pure resistance, and the frequency of the source is its natural frequency, which is what we are endeavouring to find. The most convenient way of doing this is to find C_1 and C_2 for a number of frequencies in the neighbourhood of the natural frequency of the antenna, and plot C_1-C_2 against the wavelength of the source. A typical curve is shown in Fig. 8. Where this curve cuts the axis is the natural wavelength searched for. It may be noted that the result will not be affected if the source is inducing an E.M.F. directly in the antenna, for we have seen that the effective impedance of an antenna is independent of the distribution of the E.M.F.'s.

It was not possible to take measurements at higher frequencies owing to the increasing difficulties that were met; in particular because, with the antenna used, the resistance attained very high values, rendering the deflection of the ammeter too small to be useful for accurate resistance measurements (and these are already inherently uncertain at much higher frequencies).

The values obtained are seen from Table I to confirm the theoretical deductions. No differences in the condenser settings were detectable, while the resistance appears to be slightly greater for reception than for transmission, which difference increases with increasing frequency. At 114 metres wavelength the resistance was very difficult to measure, but the resistance for transmission appears to be greater than for reception. This is probably due to the action of the antenna as a rejector circuit, for in that case the greater the resistance within the circuit the smaller the effective resistance.

Too great reliance, however, should not be placed on the small differences shown in the table, as they are within the limits of experimental error. The fact that the errors of measurement due to the arrangement of the circuit are similar for transmission and reception gives, however, greater weight to the reality of the observed differences.

To test this further, measurements were made near the natural frequency of the antenna ($\lambda=127$ metres) using thermo-ammeters having different resistances. From our previous theoretical considerations we saw that the radiation resistance for reception was greater than that for transmission and was dependent on the impedance between the foot of the antenna and the earth. It was also found that the greater this impedance, the greater would be the difference between the resistance for transmission and reception. It is to be expected, therefore, that the resistance for reception minus

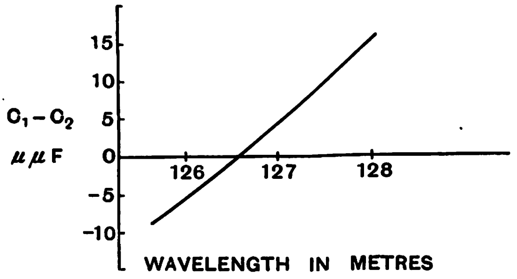


Fig. 8.—*Curve for finding the natural wavelength of an antenna.*

that for transmission would increase as the resistance of the thermo-ammeter was increased. This was actually found to be the case as is shown in Table II.

TABLE II.

Resistance of Thermo-ammeter.	(Resistance for Reception) — (Resistance for Transmission).
1 ohm	0.2 ohm
5 ohms	0.3 ,,
30 ,,	0.7 ,,

The resistance of the rest of the circuit was of the order of 8 ohms.

It was found that measurements became increasingly difficult as the resistance of the thermo-ammeter was increased, owing to the effect of the observer on the large capacity via the earth between the screen of the condenser and the counterpoise, and also owing to the capacity of the coil to earth.

The differences shown in the table are small and within the limits of experimental error for absolute values, but probably not for the differences themselves. It should be further noticed that any error caused by the reaction back on the source is greater the greater the coupling of the circuit to the source, and always causes the measured resistance to be too high. Now, with the antenna used as a transmitter the coupling is comparatively large, while it is very low when the antenna is used as a receiver. Any error of measurement due to this cause would, therefore, make the value of the resistance larger for transmission than for reception, whereas the reverse was always found to be the case.

Summary.

The intention of this investigation is to amplify the important theoretical work of Moullin and Colebrook, who have considered the case of antennæ having uniformly distributed constants. The reasons for doubting the rigid validity of this assumption is explained at some length, although in many cases it can probably be taken as a first approximation.

As an example a simple vertical antenna is considered qualitatively in order to discover what would be the likely distribution of capacity along it at low frequencies.

In this connection the meaning of the terms capacity and self-inductance per unit length are considered and defined as regards their application to alternating current. The definitions given do not bear necessarily any relation to their meaning in electrostatics, but it is shown that the electrostatic value and the alternating current value are very nearly equal when the frequency is low. This does not only apply to antennæ, but also to transmission lines, for which the problem is essentially similar. In this case, however, the approximation of taking the values of the constants as equal to the corresponding values for the electrostatic case is amply sufficient; the frequency is usually low and the return circuit is close to the outgoing wire, so that they effectively screen each other from the outside conductors and the more distant points on the same conductors.

In the mathematical analysis, which for convenience is given in an appendix, one assumption is made. This is that the distribution of the constants along an antenna is the same for transmission and reception. It is explained why this is not strictly correct, but the error caused by this assumption should be quite negligible.

It is then shown that an antenna having an E.M.F. V and an impedance Z at its base, between the foot and the earth, and a distributed E.M.F. along it can be represented by a simple circuit consisting of an impedance Z in series with another impedance Z_0, an E.M.F. V and another E.M.F. E_0. Z_0 and E_0 can, therefore, be termed the effective impedance and the effective E.M.F. of the distributed E.M.F. of the antenna respectively. Z_0 is shown to be independent of the distributed E.M.F. and of V, so that its value will be the same whether either the distributed E.M.F. or V is put equal to zero. That is, the effective impedance of the antenna is the same whether it is transmitting or receiving, and this holds irrespectively of the distribution of the constants along the antenna.

Incidentally this proposition holds equally well for any form of transmission line.

After defining the term " effective height " for a transmitting and a receiving antenna, and explaining briefly the difficulties inherent in the definitions, the following proposition is proved.

"If the distribution of the constants of an antenna is unaffected by the distribution of applied E.M.F.'s the effective height is the same for transmission and reception."

The next point to be considered is the radiation resistance. This is found to be different for transmission and reception, being in general greater for the latter. In fact, for a receiving antenna it is dependent on the impedance between the foot of the antenna and the earth and increases with it. It becomes infinite when this impedance becomes infinite. For a transmitting antenna the radiation resistance is independent of the impedance of the apparatus at the foot of the antenna.

The experimental results, which were carried out on an antenna built to have non-uniform distribution of constants, are in accord with the theoretical conclusions reached. The effective reactance and the effective resistance of the antenna were measured for reception and transmission and found to be identical except for a small difference in the value of the resistance, as was foreshadowed by the theory.

Incidentally, an accurate method of finding the natural frequency of an antenna is given. In this method no instruments likely by their reactance to affect the result are used.

APPENDIX I.

THE SEPARATION OF REACTANCE INTO ITS CAPACITY AND INDUCTANCE COMPONENTS.

Let the effective impedance of a circuit be Z_0, being composed of a resistance R_0 and a reactance X_0. It is required to find a capacity C_0 and an inductance L_0, which will represent X_0 as nearly as possible. Since there are only two quantities at our disposal, we can only hope to satisfy two conditions. These are that the reactance of the combination of C_0 and L_0 be equal to X_0 at the frequency considered, and the other that the rate of change in reactance with frequency be the same for X_0 as for the combination of C_0 and L_0.

When measuring the reactance of a circuit it is usual to measure directly the inductances or capacities which have the same reactance at the required frequency. Let these be L and C respectively ($i.e.$, $L\omega = -\frac{1}{C\omega} = X_0$).

Let us take the case in which L_0 and C_0 are put in series, so that

$$jL\omega = jL_0\omega + \frac{1}{jC_0\omega}.$$

Differentiating with respect to ω, we have for the second condition

$$\frac{dL}{d\omega} = -\frac{1}{jC_0\omega^3}.$$

From these two equations we can find L_0 and C_0. They are

$$C_0 = \frac{2}{\omega^3}\Big/\frac{dL}{d\omega}$$

and

$$L_0 = L + \frac{\omega}{2}\frac{dL}{d\omega}.$$

In the case of an antenna, when the frequency is low, it is more usual to measure the capacity C. In this case, the initial equation is

$$\frac{1}{jC\omega} = jL_0\omega + \frac{1}{jC_0\omega}.$$

Proceeding as before, differentiating with respect to ω and solving the two equations for L_0 and C_0, we obtain

$$L_0 = \frac{1}{2C^2\omega}\frac{dC}{d\omega}$$

and

$$C_0 = \frac{2C^2}{2C + \omega\frac{dC}{d\omega}}.$$

Hence by plotting L or C against ω and finding the differential ($i.e.$, the gradient of the curve), we can find the effective self-inductance and effective capacity at any required frequency.

Near even multiples of the natural frequency of an antenna, $dL/d\omega$ becomes small and the effective impedance of the antenna then resembles more that of a parallel tuned circuit as regards the variation with frequency. Near these frequencies, the usual representation of a self-inductance and capacity in series becomes very unsatisfactory, for the values of L_0 and C_0 will vary rapidly with frequency.

APPENDIX II.

Consider an element of length δr of an antenna. Let its direction cosines be l, m, n. Suppose the components of the electric intensity of an approaching wave have instantaneous values E_x, E_y, E_z, and that an E.M.F. of instantaneous value V be applied at the foot of the antenna, the frequency of the E.M.F.'s being the same.

We shall write R, L, C for the resistance, self-inductance and capacity per unit length respectively of the element δr of the antenna.

If v and i are the potential and the current respectively at any point r of the antenna, then the differential equations for the electric conditions at any point are

$$-\frac{dv}{dr} = (R + jL\omega)i - (lE_x + mE_y + nE_z) \quad \ldots (1)$$

and $$-\frac{di}{dr} = jC\omega v \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where $j = \sqrt{-1}$ and $\omega = 2\pi$ (frequency).

It should be noticed that in the two equations R, L, C, E_x, E_y, E_z are functions of r.

Eliminating v from equations (1) and (2), we have

$$\frac{d^2i}{dr^2}-\frac{1}{C}\frac{dC}{dr}\frac{di}{dr}$$
$$-(R+jL\omega)\,jC\omega i=-jC\omega\,(lE_x+mE_y+nE_z) \quad (3)$$

To solve this, suppose s is a solution of the equation

$$\frac{d^2i}{dr^2}-\frac{1}{C}\frac{dC}{dr}\frac{di}{dr}-(R+jL\omega)jC\omega i=0 \;.. \quad (4)$$

It may be noted in passing, that s is a current distribution which is possible when there is no distributed E.M.F., *i.e.*, it is a possible distribution for a transmitting antenna. If s were the complete solution of equation (4) and the constants were adjusted to satisfy the correct boundary conditions, s would be the current distribution of the antenna acting as a transmitter.

Writing $i=u\,.\,s$, we obtain

$$\frac{d^2u}{dr^2}+\frac{du}{dr}\left(\frac{2}{s}\frac{ds}{dr}-\frac{1}{C}\frac{dC}{dr}\right)=-\frac{jC\omega}{s}(lE_x+mE_y+nE_z).$$

This is a linear equation in du/dr, and the solution is

$$u=\int\frac{C}{s^2}\int(lE_x+mE_y+nE_z)sj\omega\,dr\,dr+A\int\frac{C}{s^2}dr+B$$

where A and B are constants of integration.

Let $$Q=\int\frac{C}{s^2}(lE_x+mE_y+nE_z)\,sj\omega\,dr\,dr\;.. \quad (5)$$

and $$P=\int\frac{C}{s^2}dr,\text{ so that }\frac{dP}{dr}=\frac{C}{s^2} \quad .. \quad (6)$$

Hence we can write

$$i=(Q+AP+B)s \quad .. \quad .. \quad .. \quad (7)$$

We shall also find the following formula useful

$$Q=\int\frac{dP}{dr}\int E_rsj\omega dr\,dr$$
$$=\left[P\int E_rs\,dr-\int PE_rs\,dr\right]j\omega \quad .. \quad (8)$$

where $E_r=lE_x+mE_y+nE_z$.

In these equations it should be noticed that the variables P and s are functions of the antenna constants only, while Q is a function of both the antenna constants and of the approaching field.

There now remains to insert the boundary conditions. Let the impedance of the apparatus between the foot of the antenna and earth be Z, and let i_0 be the value of the current at the foot of the antenna, then

when $r=0$, $v=V-Zi_0$ and $i=i_0$

and when $r=h$, $i=0$.

On substituting these boundary conditions, we obtain

$$i_0\left\{Z-\frac{1}{s_0C_0j\omega}\frac{ds_0}{dr}-\frac{1}{(P_0-P_h)s_0j\omega}\right\}$$
$$=V-\frac{Q_0-Q_h}{s_0(P_0-P_h)j\omega}+\frac{s_0}{jC_0\omega}\frac{dQ_0}{dr} \quad .. \quad (9)$$

where s_0, C_0, P_0, Q_0 are the values of s, C, P, Q when $r=0$ and P_h, Q_h are the values of P, Q when $r=h$.

Let us examine equation (9). It will be seen that the right-hand side is a function of the applied electric intensities and the units are those of an E.M.F. Also the coefficient of i_0 is independent of the applied electric intensities and its units are those of an impedance.

Now, comparing equation (9) with the equation

$$i_0(Z+Z_0)=V+E_0 \quad .. \quad .. \quad (10)$$

where Z_0 is the effective impedance of the antenna and E_0 is the equivalent E.M.F. at the base, which produces the same current i_0 as the approaching wave, we obtain at once

$$Z_0=-\frac{1}{s_0C_0j\omega}\frac{ds_0}{dr}-\frac{1}{(P_0-P_h)s_0^2j\omega} \quad .. \quad (11)$$

and $$E_0=\frac{s_0}{jC_0\omega}\frac{dQ_0}{dr}-\frac{Q_0-Q_h}{s_0(P_0-P_h)j\omega} \quad .. \quad (12)$$

The effective height of a transmitting antenna is defined as

$$T=\frac{1}{i_0}\int_0^h ni\,dr \quad .. \quad .. \quad (13)$$

Substituting relation (7), we have

$$T=\frac{\int_0^h n(P-P_h)s\,dr}{s_0(P_0-P_h)} \quad .. \quad .. \quad (14)$$

In the case of a receiving antenna, suppose the current produced at the foot by a vertical approaching field is i_0 and that the same current is produced by an E.M.F. V of the same frequency applied at the foot of the antenna, then the effective height R can be defined by the relation

$$R=V/E \quad .. \quad .. \quad (15)$$

In this case the approaching field must be uniform, otherwise the effective height will depend on the distribution of this field and becomes meaningless.

From equation (9) we can find i_0 in the two cases by first putting $V=0$ and then $E_r=0$. On substituting in equation (15), we have

$$R=\frac{\int_0^h n(P-P_h)s\,dr}{s_0(P_h-P_0)} \quad .. \quad .. \quad (16)$$

It will be seen that equations (14) and (16) are identical.

In considering the radiation resistance, the integral given in equation (13) is of interest. For a receiving antenna it can be shown to be

$$\frac{1}{i_0}\int_0^h ni\,dr=\frac{1}{i_0}\int_0 ns(Q-Q_h)dr$$
$$-\frac{s_0}{i_0}(Q_0-Q_h)R+R \quad .. \quad .. \quad (17)$$

The integral on the left-hand side of this equation will to a large extent govern the radiation resistance. If this integral is large, so can the radiation resistance be expected to be large.

For a transmitting antenna the value of this integral is equal to the effective height. It will be seen, therefore, that the radiation resistance is not in general the same for transmission and reception.

We shall now consider a special case, in which the constants are uniformly distributed along the antenna, and apply the equations obtained above.

An obvious solution of equation (4) is

$$s = e^{Kr}$$

where $K^2 = (R+jL\omega)jC\omega$

Therefore $P = -\dfrac{Ce^{-2Kr}}{2K}$

and $Q = -\dfrac{jC\omega e^{-Kr}}{K^2}E_r.$

Substituting in equation (11) we have

$$Z_0 = \frac{K}{jC\omega}\coth(Kh) \quad \ldots \quad \ldots \quad (18)$$

which is the well-known formula for a uniform transmission line.

Expanding, this becomes

$$Z_0 = R\frac{h}{3} + \frac{1}{hjC\omega} + \frac{hjL\omega}{3} + \ldots .$$

From equation (13), we readily find the effective height to be

$$T_s = \frac{1}{K}\tanh\left(\frac{Kh}{2}\right) \quad \ldots \quad \ldots \quad \ldots \quad (19)$$

$$= \frac{h}{2}1 + \frac{h^2LC\omega^2}{12} + \ldots$$

as obtained by Moullin.*

To compare the radiation resistance in the two cases of transmission and reception, we must evaluate

$$\frac{1}{i_0}\int_0 i\,dr$$

For transmission this is equal to the effective height and is given by equation (19). For reception the integral, assuming E_r to be uniformly distributed along the antenna, is

$$\frac{1}{K}\tanh\left(\frac{Kh}{2}\right) + \frac{jC\omega E_r}{K^2 i_0}\left[\frac{2}{K}\tanh\left(\frac{Kh}{2}\right) - h\right]$$

that is

$$\frac{1}{K}\tanh\left(\frac{Kh}{2}\right)$$

$$- \frac{jC\omega}{K\tanh\left(\frac{Kh}{2}\right)}\left[\frac{2}{K}\tanh\left(\frac{Kh}{2}\right) - h\right](Z_0 + Z)$$

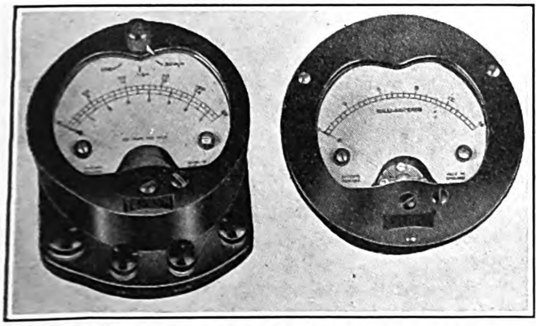
We should, therefore, expect the radiation resistance to be slightly different in the two cases. If $(Z + Z_0)$ is a pure resistance, that is, if the antenna circuit is tuned, the resistance will be greater for reception than for transmission. It is interesting to note that the difference in the radiation resistance in the two cases is dependent on the value of the impedance Z of the apparatus between the foot of the antenna and earth and is greater the greater that impedance.

---

* *Loc. cit.*

A New Range of Meters.

The accompanying illustration shows two examples of a range of small precision meters recently produced by Ferranti's. The meters are particularly suitable for general laboratory work and the price is very reasonable. Tests carried out on one of the milliammeters (0–15 range) showed that for over half the scale readings coincided with those of a sub-standard milliammeter (accuracy ½ per cent.) and at no point was the reading more than 1½ per cent. different from the sub-standard.



Ferranti Combined Portable Instrument, Type PR3a, Ranges 0–15 Milliamps, 0–7.5 volts, 0–150 volts, and the Flush Pattern, Type RIFa, 0–15 Milliamps.

A replaceable safety fuse incorporated in the case is a most useful refinement because accidents are always liable to happen and, with this arrangement, instead of having to send the instrument away for repair a new fuse can be easily fitted in ten minutes. We had some doubt as to whether a fuse could actually be a sufficiently certain protection to an instrument taking so small a current. To satisfy ourselves we applied an overload current of about 100 per cent. and watched the needle carefully. The fuse went before the pointer had traversed one-third of the scale, so that the pivots were not called upon to withstand the shock of a full scale deflection.

Good Quality in H.F. Amplifiers.

By C. C. Inglis, A.M.I.E.E.

WITH the advance in the design of low frequency amplifiers for good quality reproduction, it has been questioned whether the frequencies let through by a tuned anode arrangement for high frequency amplification, using the new screened valve, are consistent with the flat characteristics of the low frequency resistance-coupled amplifier.

It is obvious that it is useless providing a flat characteristic in the low frequency amplifier up to say 6,000 cycles, if the high frequency end does not pass them.

The average low loss coil *per se* has much too narrow a resonance curve to do this, but as until now, valves of about 20,000 ohms have been used in conjunction with these coils, the resonance curve has been effectively broadened so as to allow the necessary band to pass.

The following analysis was made to arrive at the width of a resonance curve at a large fraction of its height :—

Consider the impedance of a coil of inductance L and resistance R when shunted by a condenser of capacity C.

It can be shown that if Z = impedance at ω frequency

then $$\frac{1}{Z^2} = \omega^2C^2 - \frac{2\omega^2LC - 1}{R^2 + \omega^2L^2}$$

at resonance

$$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{L}}$$

giving

$$Z = \frac{L}{CR}$$

Consider the values of ω which would reduce the impedance to some fixed fraction $1/n$ of this maximum resonant value. Then to find the two values of ω for this condition put

$$\frac{n^2C^2R^2}{L^2} = \omega^2C^2 - \frac{2\omega^2LC - 1}{R^2 + L^2\omega^2}$$

Now, if $\omega_A \cdot \omega_B$ are the two real roots of this equation it can be shown that

$$\omega_A{}^2 - \omega_B{}^2 = 2\frac{R}{L}\sqrt{n^2 - 1}\left[\sqrt{\frac{1}{LC} + \frac{(n^2+1)^2}{L(n^2-1)} \cdot \frac{R^2}{L^2}}\right]$$

(See appendix I.)

For all ordinary values of L, C, R, and provided n is small, the expression in the bracket is approximately equal to the resonant angular frequency ω of the circuit since R^2/L^2 is very small compared with $1/LC$ (about 1 in 10^7) ;

or $$\omega_A{}^2 - \omega_B{}^2 = 2\frac{R}{L}\sqrt{n^2 - 1} \cdot \omega$$

$$\therefore \quad (\omega_A - \omega_B)(\omega_A + \omega_B) = 2\frac{R}{L}\sqrt{n^2 - 1} \cdot \omega$$

but $$\omega_A - \omega_B = 2\omega.$$

Hence

$$\omega_A - \omega_B = \frac{R}{L}\sqrt{n^2 - 1}$$

This is not quite true, as a resonance curve is not quite symmetrical about its maximum ordinate.

For small values of n, however, the error is inappreciable.

In other words the width in cycles per second of a resonance curve at $1/n^{\text{th}}$ of its height is

$$\frac{R}{2\pi L}\sqrt{n^2 - 1}$$

cycles on the above assumptions.

Consider a circuit of 183μH, .0002μF, and 5 ohms, which is representative of a good low loss coil tuned to 830kC (2LO).

Let $$n = 1.05.$$

That is the condition when the impedance of the circuit is 5 per cent. less than its maximum.

Then width—

$$= \frac{R}{2\pi L}\sqrt{n^2 - 1} = \frac{R}{2\pi L} \cdot .346 \text{ cycle}$$

$$= \frac{5}{2.\pi.183 \times 10^{-6}} \times .346 = 1{,}500 \text{ cycles.}$$

This value is much too small for good quality.*

Valve Damping.

It can be shown that the equivalent resistance of a valve of ρ A.C. resistance which can be inserted in a circuit L, C, R, is ω^2L^2/ρ provided that R is small compared with ωL. (See appendix II.)

This is always the case, except in that of resistance wound H.F. transformers. Consequently with the coil under consideration and a valve of 20,000 ohms, the equivalent resistance to be inserted is

$$\frac{(2.\pi.830{,}000)^2\times(183\times 10^{-6})^2}{20{,}000} = 45 \text{ ohms.}$$

This makes a total coil resistance of 50 ohms.

Now with $R = 50$ ohms at $n = 1.05$ width becomes

$$.346.\frac{50}{2\pi L} = 15{,}000 \text{ cycles.}$$

A satisfactory value.

This is the band that would be passed with a maximum reduction of 5 per cent. provided there was no reaction or feedback in the circuit, but no doubt in practice the band is reduced by these causes.

Turning now to the effect of the new high impedance valve of, say, 100,000 ohms.

The equivalent resistance is $\omega^2L^2/100{,}000$.

$$\begin{aligned} L &= 183 \times 10^{-6}\text{H} \\ \omega &= 2\pi.830{,}000 \\ &= 9 \text{ ohms} \end{aligned}$$

making a total of 14 ohms in the coil.

This gives a band width with $n = 1.05$ of 4,200 cycles, or only 2,100 cycles either side of the maximum.

It is therefore seen that to pass a band of frequencies of only 4,000 the station will have to be tuned to one side of the peak, so as to pass one sideband correctly instead of two sidebands partially.

This is found to be necessary in superheterodyne circuits, where feedback produces very sharp response curves at the intermediate frequency.

In fact, the alteration in tone is very noticeable as the oscillator is slightly varied.

The results of the above remarks show that care must be taken not to use a valve of too high impedance with a tuned anode circuit, if good quality is to be maintained.

If a transformer is used, it is clear that the damping action of the valve is considerably reduced, and that good quality cannot be attained with this arrangement.

Assuming that a resonance peak of 12,000 cycles (at 5 per cent. maximum reduction) is required, then equivalent coil resistance of 22 ohms is required.

With a coil of 5 ohms resistance, this results in a resistance, due to the valve, of 17 ohms or a valve resistance of, say, 53,000 ohms.

It must be pointed out that all the above calculations are based on a 5 per cent. cut off, and naturally with a higher cut off, say 10 per cent. ($n = 1.11$) the band of frequencies passed are broader, enabling a higher impedance valve to be used.

APPENDIX I.

$$\frac{n^2C^2R^2}{L^2} = \omega^2C^2 - \frac{2\omega^2LC - 1}{R^2 + \omega^2L^2} \quad \text{(See text)}$$

by rearrangement

$$n^2C^2R^4 + n^2C^2R^2L^2\omega^2 = L^2\omega^2C^2R^2 + \omega^4L^4C^2 - 2\omega^2L^3C + L^2$$

$$\therefore \quad \omega^4L^4C^2 - \omega^2(2L^3C + (n^2-1)C^2R^2L^2) - (n^2C^2R^4 - L^2) = 0$$

or $$\omega^4 - \omega^2\left(\frac{2}{LC} + (n^2-1)\frac{R^2}{L^2}\right) + \left(\frac{1}{L^2C^2} - n^2\frac{R^4}{L^4}\right) = 0$$

Let

$$\frac{2}{LC} + (n^2-1)\frac{R^2}{L^2} = 2\omega_R^2 \quad .. \quad (1)$$

and

$$\frac{1}{L^2C^2} - n^2\frac{R^4}{L^4} = \omega_r^4 \quad .. \quad .. \quad (2)$$

Then

$$\omega^4 = \omega^2 2\omega_R^2 + \omega_r^4 = 0$$

and

$$\omega^2 = \frac{2\omega_R^2 + \sqrt{4\omega_R^4 - 4\omega_r^4}}{2} = \omega_R^2 \pm \sqrt{\omega R^4 - \omega_r^4}$$

If $\omega_A^2 . \omega_B^2$ are roots.
Then

$$\omega_A^2 - \omega_B^2 = 2\sqrt{\omega_R^4 - \omega^{r4}} \quad .. \quad (3)$$

Now from (1)

$$\omega_R^4 = \frac{1}{4}\left(\frac{2}{LC} + (n^2-1)\frac{R^2}{L^2}\right)^2 = \frac{1}{L^2C^2} + \frac{(n^2-1)}{LC}\frac{R^2}{L^2} + \frac{(n^2-1)^2}{4}\cdot\frac{R^4}{L^4}$$

---

* [The author regards decrease of 5 per cent. in the current as the limiting factor in fixing the width of the band. In our opinion this is far too stringent.—EDITOR.]

(from 2)

$$\omega_r{}^4 = \frac{1}{L^2C^2} - n^2\frac{R^4}{L^4}$$

$$\therefore \quad \omega_R{}^4 - \omega_r{}^4 = \frac{(n^2-1)R^2}{L^3C} + \frac{n^4-2n^2+1}{4}\,\frac{R^4}{L^4} + \frac{4n^2}{4}\cdot\frac{R^4}{L^4}$$

or

$$\omega_R{}^4 - \omega_r{}^4 = \frac{(n^2-1)R^2}{L^3C} + \frac{(n^2+1)^2}{4}\cdot\frac{R^4}{L^4}$$

$$= \frac{R^2}{L^2}(n^2-1)\left[\frac{1}{LC} + \frac{(n^2+1)^2}{4(n^2-1)}\cdot\frac{R^2}{L^2}\right] \quad .. \quad (4)$$

From 3 and 4 we get

$$\omega_A{}^2 - \omega_B{}^2 = 2\frac{R}{L}\sqrt{n^2-1}\left[\sqrt{\frac{1}{LC} + \frac{(n^2+1)^2}{4(n^2-1)}\cdot\frac{R^2}{L^2}}\right]$$

APPENDIX II.

Consider the circuit as shown in the figure with V volts applied.

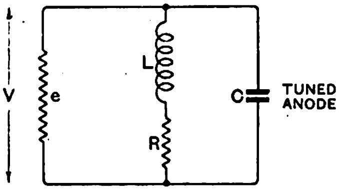
In practice since R is very small compared with ωL the current through an inductive branch of the tuned circuit is sensibly $V/\omega L$.

$\therefore$ Power lost in R is $(V/\omega L)^2 R$.

Now power lost in $\rho = V^2/\rho$

Making a total of $V^2\left(\frac{R}{\omega^2L^2} + \frac{1}{\rho}\right) \quad .. \quad (1)$

Let the equivalent circuit to the above arrangement be L, C, S, where S is the combined value of ρ and R.



Power lost in this case $\left(\frac{V}{\omega L}\right)^2 . S . \quad .. \quad (2)$

If 1 and 2 are equal,

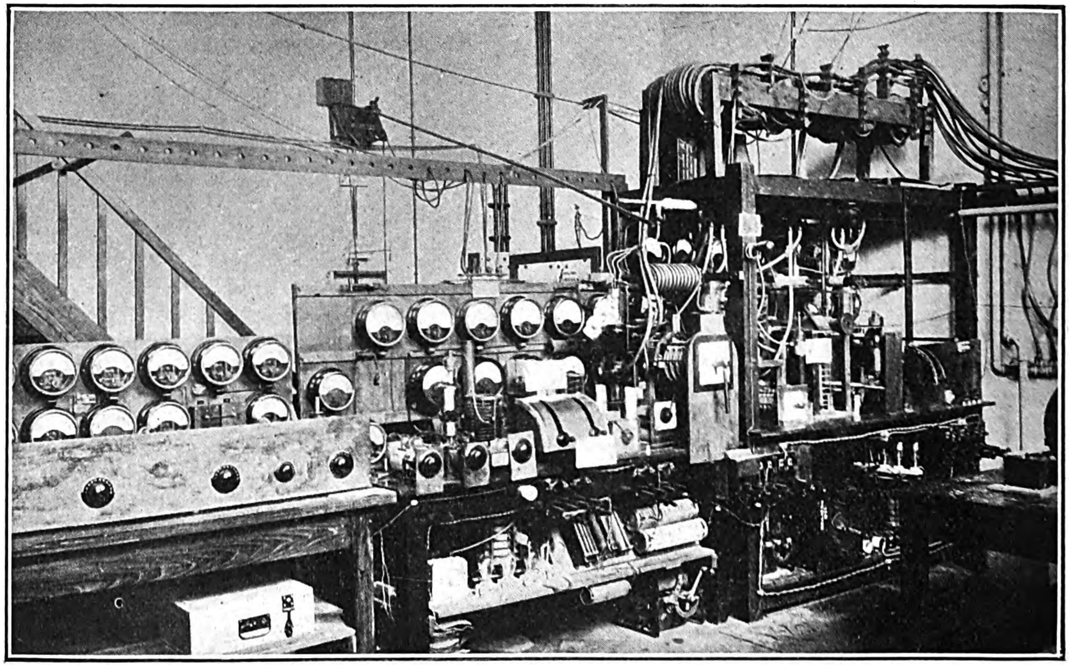
then

$$\frac{V^2}{\omega^2L^2} . S = V^2\left(\frac{R}{\omega^2L^2} + \frac{1}{\rho}\right)$$

$$\text{or } S = R + \frac{\omega^2L^2}{\rho}$$

So that coil resistance is increased by ω^2L^2/ρ

Holland's Short Wave Station.



The first photograph to be taken of the Dutch Short Wave Station PCJJ, which has been conducting world-wide broadcast transmissions for some months past with such remarkable success.

Parasitic Oscillations in the Case of a Tuned-Anode Oscillator.

By M. Reed, M.Sc., A.C.G.I., D.I.C.

IN a previous article[*] the subject of Parasitic Oscillations was treated quit generally. In this article a particular case of Parasitic Oscillations is considered, and it is shown how these Oscillations were encountered in actual practice.

Introduction.

During the course of an ordinary laboratory test, it was desired to obtain a curve between the value of the mutual induction required to start oscillating a tuned-anode valve oscillator and the position of the anode tapping point. To obtain this curve a tuned-anode oscillator with anode tap was connected up as shown in Fig. 1. The particulars of the circuit were as follows :—

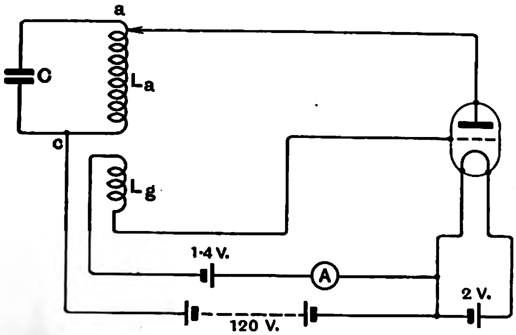


Fig. 1

Capacity of condenser $C = 0.0567\ \mu\text{F}$.
Inductance of coil $La = 0.480$ henry.
Resistance = 25 ohms.
Inductance of coil $Lg = 0.08$ henry.
Frequency of oscillatory circuit = 965 cycles/sec.

It was found that in this case the curve between the mutual induction required to bring the valve to the point of oscillating and the position of the anode tapping point was as shown by the curve marked " Position B " in Fig. 3. For positions of the tapping point below 0.9 it was found that for values of the mutual induction lower than those required to produce audible oscillations the micro-ammeter *A* gave a fairly large reading, thus indicating that an oscillation above audio-frequency was present. The presence of a higher frequency oscillation was further proved by means of a wavemeter.

When the connections to both the grid and anode coils were reversed, the corresponding curve between mutual induction and position of tapping point was as shown by the curve marked " Position A " in Fig. 3.

This curve will be recognised as the one which is obtained for a tuned anode oscillator with anode tap under normal conditions. In this case it was found that no deflection was obtained in the micro-ammeter for values of the mutual induction below those required to start the audio oscillation, nor could an oscillation be detected by means of a wavemeter.

Since in the second case the connections to both the grid and anode coils were reversed, it would be expected that the behaviour of the oscillator would be the same in this as in the first case.

In the following a full investigation of the two cases is given and the curious behaviour of the oscillator is explained.

Description of the Mutual Inductance Used.

Fig. 2a gives an elevation and side view, and Fig. 2b a photograph, of the inductance.

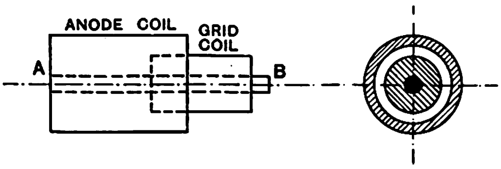


Fig. 2a.

The anode coil is wound in ten equal sections, each section being brought out to a pair of terminals, thus giving the anode tapping points. The grid coil is wound in four equal sections whose ends are brought out to terminals. The latter slides coaxially inside the former on a graduated rod. The inductance was calibrated against a standard so that the value of the mutual induction corresponding to any reading on the graduated rod was known.

---

[*] " The Suppression of Parasitic Oscillations," *E.W. & W.E.* of Dec., 1927, p. 725.

Reference to Figs. 1 and 2a will show that the ends marked *A* and *B* in Fig. 2a correspond in Fig. 1 to opposite ends of the coils. Thus in the case of "Position B" the connections to the anode and grid respectively are as far apart as possible.

The Investigation.

In this section the tests carried out are described as briefly as possible. In all the tests except Test 1, the position of the tapping point was kept fixed at 0.8 of "all in" because Fig. 3 shows this position to give the worst result.

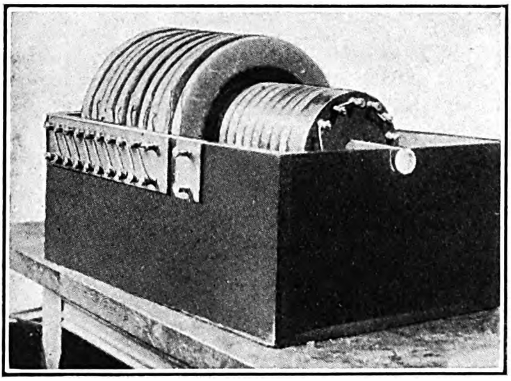


Fig. 2b. *Photograph showing the Mutual Inductance used.*

The valve used was of the ordinary D.E.R. Type, having an amplification factor of 9 and an internal resistance of 22,000 ohms.

TEST 1.

The Effect of the Audio Oscillatory Circuit on the Parasitic Oscillation.

In this test the circuit of Fig. 1 was used and the peak voltage between the end of the coil marked *c* and each of the tapping points was measured.

The "Peak-voltmeter" shown in Fig. 5 was used for this purpose; the peak voltage being indicated by the electrostatic voltmeter.

TABLE I.

Peak Voltmeter connected between the Point *c* and :	Peak Voltages.	
	Using Anode Tap of 0.8.	Using Anode Tap of 0.6.
All in	0 volts	0 volts
0.9	25 ,,	10 ,,
0.8	62 ,,	55 ,,
0.7	75 ,,	70 ,,
0.6	72 ,,	80 ,,
0.5	70 ,,	85 ,,
0.4	66 ,,	84 ,,
0.3	55 ,,	70 ,,
0.2	30 ,,	50 ,,
0.1	5 ,,	10 ,,

From the readings given in Table I it is seen that when the parasitic oscillation is present the effect of the condenser *C* in the audio oscillatory circuit is to connect the two portions of the anode coil which are separated by the anode tap, in parallel.

The audio oscillatory circuit therefore represents, as far as the parasitic oscillation is concerned, an inductance consisting of two coils in parallel.

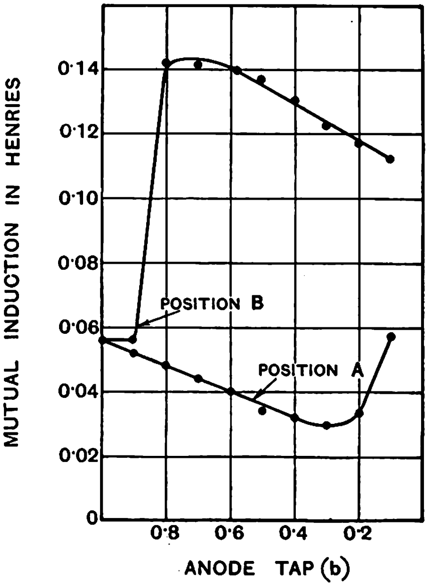


Fig. 3

The condenser *C* can therefore be replaced by a piece of copper wire, and the parasitic oscillations can be investigated without interference from the audio oscillation.

TEST 2.

The Strength and Frequency of the Parasitic Oscillations.

Measurements of frequency were made by means of the circuit shown in Fig. 4. The coil *L* was loosely coupled to the oscillator under investigation, and resonance was indicated by means of the galvanometer *A* placed in the anode circuit of the rectifying valve *V*. The reading of the galvanometer at resonance was taken as a measure of the strength of the detected oscillation.

The connections of Fig. 1 were used, the condenser *C* being replaced by a piece of copper wire as explained in Test 1. The voltage on the anode was kept constant at 120 volts, and the tapping point was kept fixed at 0.8 of " all in." The position of the grid coil was varied and the corresponding frequency and amplitude were recorded.

TABLE II.

AMPLITUDES AND FREQUENCIES FOR POSITION B.

Zero Reading of Galvanometer = 9 divisions.

Position of the Grid Coil.	Amplitude of the Oscillation.	Frequency of the Oscillation.
cms.	Divisions.	Cycles/Sec.
24	18.5	4.0×10^4
22	128	4.2×10^4
20	125	4.16×10^4
18	120	4.08×10^4
16	120	4.02×10^4
14	120	4.00×10^4
13	120	3.93×10^4
12	120	3.90×10^4
11	118	3.875×10^4
10	80	3.85×10^4
9	26	3.83×10^4
8	17	3.83×10^4
7	14	3.84×10^4
6	14	3.87×10^4
5	13	3.885×10^4
4	12.5	3.90×10^4
2	12.0	4.00×10^4
0	11.0	4.08×10^4

Table II gives the measurements obtained in the case of " Position B " and Fig. 7 shows the frequency curve obtained. In this case the harmonics were neglected, and the amplitude measurements refer to the fundamental.

From the measurements given in Table II it is seen that there is a sudden change in amplitude somewhere near 10 cms. There is no jump in the frequency, which changes quite slowly.

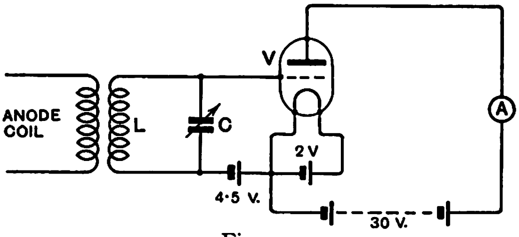


Fig. 4.

The measurements of frequency for " Position A " are given in Table III.

TABLE III.

FREQUENCIES FOR POSITION A.

Position of Grid Coil.	Frequency of Oscillation.
24 cms.	22.0×10^4 cycles/sec.
	18.1×10^4 ,,
	14.6×10^4 ,,
	10.95×10^4 ,,
	7.45×10^4 ,,
	3.80×10^4 ,,
22 ,,	8.85×10^4 ,,
	4.30×10^4 ,,
21 ,,	4.85×10^4 ,,
17 ,,	8.96×10^4 ,,
16 ,,	17.20×10^4 ,,
	8.60×10^4 ,,
15 ,,	17.00×10^4 ,,
	8.60×10^4 ,,
14 ,,	17.00×10^4 ,,
	8.74×10^4 ,,
13 ,,	9.20×10^4 ,,
12 ,,	9.20×10^4 ,,
11 ,,	9.20×10^4 ,,
10 ,,	9.20×10^4 ,,

From the measurements of Table III it is seen that at 24 cms. six harmonics could be detected. From 17 cms. and onwards the frequency of the fundamental is much higher than that of the fundamental at 24 cms. to 21 cms.

From 21 cms. to 17 cms. exclusive no oscillation could be detected. Similarly at 10 cms. and downwards.

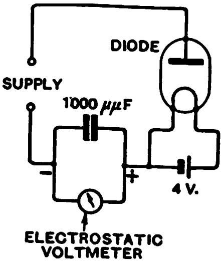


Fig. 5.

Test 3

The Effect of a Condenser Connected Across the Anode and Grid.

The circuit of Test 2, " Position B," was used, and in addition a variable condenser was connected across the anode and grid terminals of the oscillator. The tapping point was kept fixed at 0.8 of " all in " and the value of the mutual induction was kept constant.

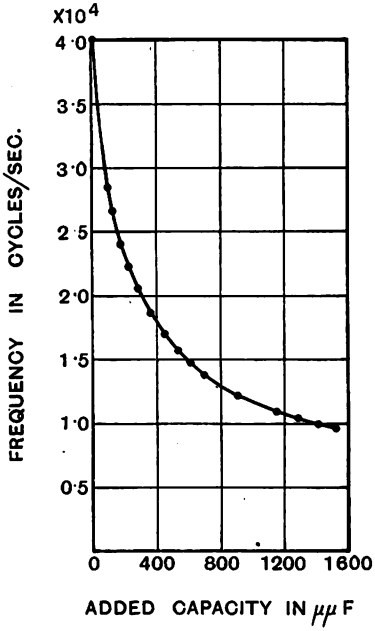


Fig. 6.

The change in frequency with variation of the added capacity was recorded, and the resulting curve is shown in Fig. 6.

The above test was repeated for " Position A." It was found that small capacities connected across the anode and grid enabled an oscillation to be detected during the interval of 21 cms. to 17 cms., although no oscillation could be detected if this capacity was removed (see Table III).

The following test was therefore carried out. The tuned circuit of the frequency indicator (Fig. 4) was kept at a fixed value, and the condenser connected across the anode and grid of the oscillator was varied until a resonance point indicated by the galvanometer in the anode circuit of the frequency indicator was obtained. This was repeated for different positions of the grid coil, and, as seen from the measurements given in Table IV, the effect of the added capacity was to start an oscillation from 21 cms. to 17 cms. which appears to be the same as the oscillation at 24 cms. to 21 cms. The effect of this capacity is also to stop the valve from oscillating for positions of the grid coil below 18 cms.

TABLE IV.

Position of the Grid Coil.	Capacity required to start the Oscillation.
24 cms.	115 μμF
22 ,,	120 ,,
20 ,,	120 ,,
19 ,,	140 ,,
18 ,,	160 ,,
17 cms. and onwards.	No oscillation could be detected.

Test 4.

From the results of the previous test it is seen that in the case of " Position B " a condenser connected across the anode and grid has the effect of reducing the frequency of oscillation. It therefore seems that the capacity which may exist between the

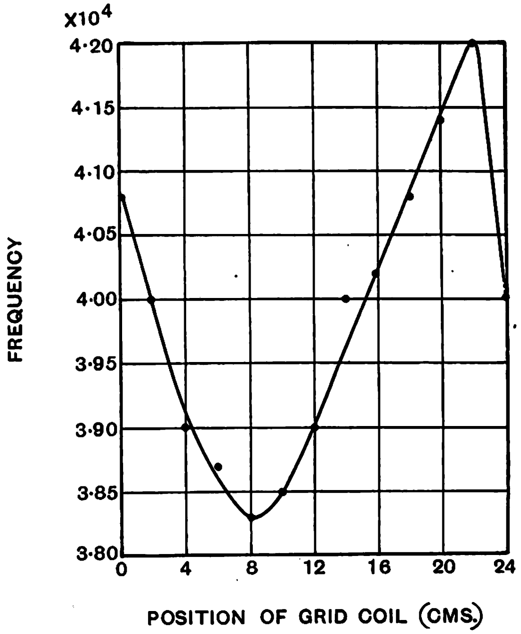


Fig. 7.

anode and grid, *i.e.* the inter-electrode capacity, or the capacity between the coils of the mutual inductance, or both these capacities in parallel, forms part of the oscillatory circuit. If this is so then the complete oscillatory circuit would consist of the grid coil, the anode coil (consisting of two parts in parallel) and the stray capacity between the grid and the anode. This will be recognised as the Hartley circuit.

It is possible, however, that the introduction of the condenser across the anode and grid in Test 3 caused the oscillation to be established in the Hartley circuit, and that previous to the introduction of the condenser the oscillation was confined to a different circuit.

To verify this point a megohm was connected between the negative end of the filament and the terminal of the grid coil which was not connected to the grid. This resistance was thus in the Hartley circuit, and it therefore prevented any tendency that this circuit might have to oscillate. An oscillation was, however, detected, and its frequency was found to be 5.6×10^4 cycles/sec. This frequency did not alter appreciably with the position of the grid coil, but the oscillation ceased for positions of the grid coil below 6 cms.

Test 5.

Determination of the Natural Frequency of the Components of the Oscillator.

The natural frequency of the grid coil was first determined. The method employed is indicated in Fig. 8a. The frequency of the oscillator was varied by means of condensers C_1 and C_2 until a "kick" curve was obtained as indicated by the thermo-ammeter. Such a curve is shown in Fig. 8b.

The natural frequency of the coil was then calculated by determining the value of the capacity C and substituting in the formula :—

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

where f_0 = natural frequency of grid coil.
L = inductance of grid coil.

Since only an approximate value of f_0 was required the value of C was assumed to be given by $\frac{Ca + Cb}{2}$.

[The theory of this method is fully explained in *J.I.E.E.*, Vol. 63, p. 397.]

The natural frequency of the grid coil was found to be 5.4×10^4 cycles/sec.

As far as the anode coil is concerned, we have to determine its natural frequency when it consists of two portions in parallel and separated by the tapping point. To obtain this, the method indicated in Fig. 8c was used. The two ends of the anode coil were shorted, and one section of the coil (corresponding to a particular tapping point) was connected to the grid and filament terminals of the valve voltmeter (see Fig. 4) which has been used for the frequency measurements. C_1 and C_2 (see Fig. 8c) were then varied until an indication of resonance was obtained. The value of the capacity at resonance gave the means of calculating the natural frequency of the anode coil for the particular tapping point.

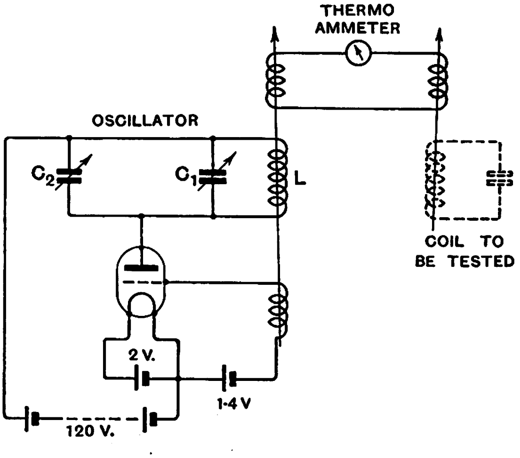


Fig. 8a.

The frequency of the anode coil for the 0.8 tapping point was found to be 9.8×10^4 cycles/sec.

The natural frequency of the Hartley circuit was calculated as follows :—

Consider first the value of the stray capacity between the anode and grid.

From the curve of Fig. 6, the following values can be taken :—

	Added capacity =		Cycles/sec.
1.	200 $\mu\mu$F	frequency	= 2.25×10^4
2.	300 $\mu\mu$F	,,	= 1.95×10^4
3.	400 $\mu\mu$F	,,	= 1.725×10^4
4.	600 $\mu\mu$F	,,	= 1.475×10^4
5.	1,200 $\mu\mu$F	,,	= 1.075×10^4

Let the stray capacity between the anode and grid be denoted by C. Then, since the same inductance was used in all the cases, we have from 1 and 3 :—

$$\frac{400 + C}{200 + C} = \left[\frac{2.25}{1.725}\right]^2 = 1.7.$$

$$\therefore C = 86 \ \mu\mu\text{F}.$$

Similarly from 2 and 4 : $C = 105 \ \mu\mu\text{F}$
and from 4 and 5 : $C = 82 \ \mu\mu\text{F}$.

The average of these three results gives

$$C = 90 \ \mu\mu\text{F}$$

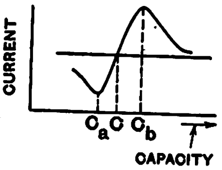


Fig. 8b.

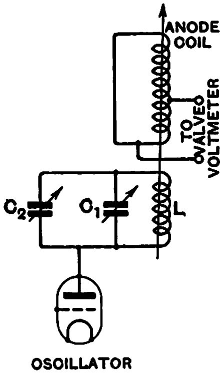


Fig. 8c.

Consider next the anode coil. This consists of two portions in parallel, and for a tapping position of 0.8 the value of each portion is :—

Larger part = 0.48 × 0.8 = 0.384 henry.
Smaller „ = 0.48 × 0.2 = 0.096 „

Inductance of these two portions in parallel = 0.077 henry. The mutual induction between the two parts is neglected. The inductance of the grid coil will remain unaltered, its value being 0.08 henry.

The Hartley circuit is therefore as shown in Fig. 9.

For the sake of simplicity we shall consider the case when the position of the grid coil is at 0 cm.; the mutual induction between the anode and grid coils is then extremely small, and the inductance of the anode and grid coil in series is then equal to 0.157 henry.

The natural frequency of the Hartley circuit is then 4.18×10^4 cycles/sec.

The Parasitic Oscillatory Circuits.

From the knowledge of the natural frequencies it is now possible to give the values of each of the possible parasitic oscillatory circuits.

Consider the grid coil. Its natural frequency has been estimated as 5.4×10^4, therefore its effective self capacity is practically 100 $\mu\mu$F.

Consider now the anode coil. For a tapping position of 0.8 the natural frequency is 9.8×10^4 and the inductance is 0.077 henry; therefore the effective self capacity is about 30 $\mu\mu$F.

The components of the Hartley circuit have already been estimated. A complete diagram is shown in Fig. 10, and from this figure it is seen that the possible oscillatory circuits are :—

	Frequency =
1. The anode coil.	9.8×10^4 cycles/sec.
2. The grid coil.	5.4×10^4 „
3. The Hartley circuit.	4.18×10^4 „

From the frequency measurements of Test 2 it is seen :—

(*a*) The Hartley circuit oscillates for all positions of the grid coil in the case of "Position B."

(*b*) In the case of "Position A," the Hartley circuit oscillates at 24 cms. to 17 cms., and the anode coil oscillates at 17 cms. to 10 cms.

From the measurements of Test 4 it is seen that the grid coil will oscillate in the case of "Position B" if the Hartley circuit is prevented from oscillating by the insertion of a megohm in its circuit.

It is now necessary to explain why the oscillations charge from one circuit to another, and to account for the measurements of Tables II and III.

The Effective Mutual Induction between the Anode and Grid Coils.

From the foregoing tests it is seen that the position of the grid coil influences the nature of the parasitic oscillation. Since the anode coil consists of two parallel portions during the presence of a parasitic oscillation, therefore the value of the mutual induction between the anode and grid coils is different from the value that it has when the valve is oscillating at the normal audio frequency.

The diagram, Fig. 9a, shows how the

current through the anode coil divides into two parts C_1 and C_2.

These currents flow in opposite directions, and hence the mutual induction between each part of the anode coil and the grid coil must be of different sign. In the case of "Position B" for a tapping position of 0.8 the sign of the mutual induction between the larger portion of the anode coil, *i.e.*, the portion carrying C_1 and the grid coil is negative. The reason for this will be seen when it is considered that the connections to the anode and grid coils are such that under normal conditions the audio oscillation would be maintained, *i.e.*, the sign of the mutual induction between the whole of the anode coil and the grid coil is negative.

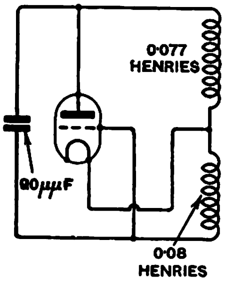


Fig. 9.

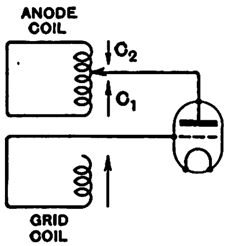


Fig. 9a.

Appendix I shows how the effective mutual induction between the anode and grid coils can be calculated when the Hartley oscillation is present, *i.e.*, when the anode and grid coils are in series.

The component mutual inductances given in the final equation for the value of the effective mutual induction between the anode and grid coils were measured. Table V gives the values of the effective mutual induction for all positions of the grid coil for both "Position A" and "Position B" for an anode tapping position of 0.8.

From the measurements given in Table V it is seen that whereas the sign of the mutual induction is negative for all positions of the grid coil in the case of "Position B," it is only negative after about 18 cms. in the case of "Position A."

The values of effective mutual induction given in Table V will only be true when the Hartley circuit is oscillating. Since the anode coil will consist of two portions in parallel if either the grid or the anode circuit oscillates, it can be assumed that Table V still gives an indication of the sign of the mutual induction if either of the latter two circuits oscillates, although the actual values of the mutual induction will not hold.

TABLE V.

VALUES OF EFFECTIVE MUTUAL INDUCTION.

Position A.

Position of the Grid Coil.	M_2	M_3	Ma	Mg	Effective Mutual Induction.
cms.					
0	0.01184	0.0093	0.00038	0.0038	0.0021
4	0.0186	0.01625	0.0079	0.0094	0.0087
8	0.0312	0.01754	0.00815	0.0071	0.0075
12	0.053	0.0364	0.0224	0.007	0.015
16	0.0822	0.03667	0.0178	−0.0136	0.0021
20	0.109	0.02835	0.0051	−0.0388	−0.0165
22	0.120	0.0224	−0.00115	−0.0531	−0.026
24	0.126	0.017	−0.0065	−0.049	−0.028

Position B.

Position of the Grid Coil.	M_2	M_3	Ma	Mg	Effective Mutual Induction.
0	0.0200	0.00145	−0.00665	−0.0032	−0.0049
4	0.03325	0.0020	−0.0079	−0.0078	−0.0079
8	0.0563	0.0029	−0.0102	−0.0144	−0.0123
12	0.08545	0.0042	−0.0136	−0.0296	−0.0216
16	0.1130	0.00717	−0.0143	−0.0468	−0.0305
20	0.1260	0.0123	−0.0112	−0.0592	−0.0352
22	0.1260	0.01595	−0.00765	−0.0532	−0.0304
24	0.1210	0.0220	−0.0010	−0.0510	−0.026

Explanation of the Results obtained in "Position B."

Table V has shown that the sign of the effective mutual induction between the anode and grid coils is negative for all positions of the grid coil in the case of "Position B." It is therefore possible for only the Hartley circuit or the grid coil to oscillate. The anode coil cannot oscillate because its natural frequency is above that of the grid coil, and hence the sign of the mutual induction must be positive for the anode coil to oscillate.*

The frequency measurements of Table II show that the Hartley circuit oscillates. The valve probably prefers to maintain this circuit in oscillation because it is the one which is most closely coupled to it.

---

* *Loc. cit.*, p. 731.

Test 4 has shown that the grid coil will oscillate if the Hartley oscillation is prevented.

The changes in frequency that take place as the position of the grid coil is varied (see Table II) can be explained as follows. If *La* is the effective inductance of the anode coil, *Lg* the inductance of the grid coil, and *M* the effective mutual induction between them, then, since the sign of *M* is negative, the effective inductance of the anode and grid coils in series is $La + Lg - 2M$. Therefore as the coupling between the anode and grid coils is increased, the effective inductance will be decreased. At the same time, since the grid coil is being moved nearer to the anode coil, therefore the capacity between these coils, which has been shown in Test 4 to be part of the Hartley circuit, is increased. The decrease in effective inductance will raise the frequency of oscillation, whereas the increase in capacity will tend to lower the frequency of oscillation. Hence, while the increase of capacity is greater than the decrease in inductance, the frequency will fall, and on the latter predominating the frequency will rise. Fig. 7 shows this to be the case, the decrease in inductance predominating from 9 cms. to 22 cms. The low frequency at 24 cms. is probably due to the low value of effective mutual induction for this position of the grid coil (see Table V).

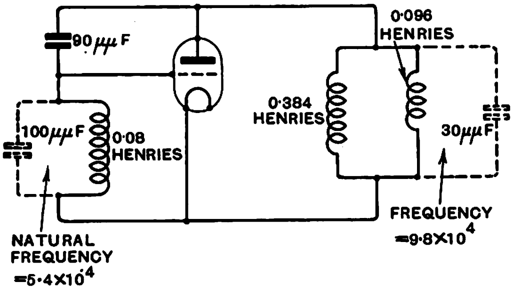


Fig. 10.

The changes in amplitude (see Table II) for this position can be explained as follows. The natural frequency of the grid coil was found to be 5.4×10^4 cycles/sec., when the inductance of the grid coil was at its normal value of 0.08 henry. When the grid coil is part of the oscillator its effective inductance is given by $Lg - M$, and its value changes as the position of the grid coil is varied. From Table V it is seen that the effective inductance of the grid coil is a minimum at 20 cms. The natural frequency of the grid coil will therefore be highest at 20 cms. and lowest at 0.2 cm. From Fig. 10 it is seen that the grid coil acts as a rejector circuit to an oscillation existing in the Hartley circuit; and, since the value of the natural frequency of the grid coil is near to the frequency of the Hartley oscillation, the grid coil will introduce a fairly high resistance into the Hartley circuit. The value of this resistance will increase as the natural frequency of the grid coil approaches the frequency of the Hartley oscillation—that is, as the effective inductance of the grid coil is increased.

TABLE VI.

Position of the Grid Coil.	*Mg*.	$L_{eff} = Lg - Mg$.	$\frac{1}{\omega L_{eff}}$	$\frac{1}{R_{eff}}$	R_{eff} in Ohms.	Theoretical Amplitude.
0.2 cms.	0.0036	0.0764	5.22×10^{-5}	2.71×10^{-5}	3.7×10^4	3.4 cms.
4 ,,	0.0063	0.0737	5.40×10^{-5}	2.90×10^{-5}	3.45×10^4	3.9 ,,
8 ,,	0.0147	0.0653	6.10×10^{-5}	3.60×10^{-5}	2.78×10^4	6.0 ,,
12 ,,	0.0294	0.0506	7.88×10^{-5}	5.37×10^{-5}	1.86×10^4	23 ,,
16 ,,	0.0486	0.0314	12.7×10^{-5}	10.2×10^{-5}	0.98×10^4	48 ,,
20 ,,	0.0570	0.0230	17.3×10^{-5}	14.8×10^{-5}	0.68×10^4	100 ,,
22 ,,	0.0560	0.0240	16.6×10^{-5}	14.1×10^{-5}	0.71×10^4	91 ,,
24 ,,	0.0510	0.0290	13.3×10^{-5}	11.2×10^{-5}	0.925×10^4	54 ,,

$Lg = 0.08$ henries.
$c = 100 \mu\mu F$. $\omega = 2\pi \times 10^4 \times 4$. $\omega C = 2.51 \times 10^{-5}$.

The effective resistance introduced into the Hartley circuit is given by:—

$$\frac{1}{R_{eff}} = \frac{1}{\omega Lg_{eff}} - \omega C.$$

Where C = self capacity of the grid coil.
= 100 $\mu\mu$F.
Lg_{eff} = effective inductance of the grid coil.
ω = $2\pi \times$ frequency of Hartley oscillation.
= $2\pi \times 4 \times 10^4$.

4×10^4 cycles/sec. is taken as a mean value for the frequency of the Hartley oscillation. The resistance of the grid coil is neglected.

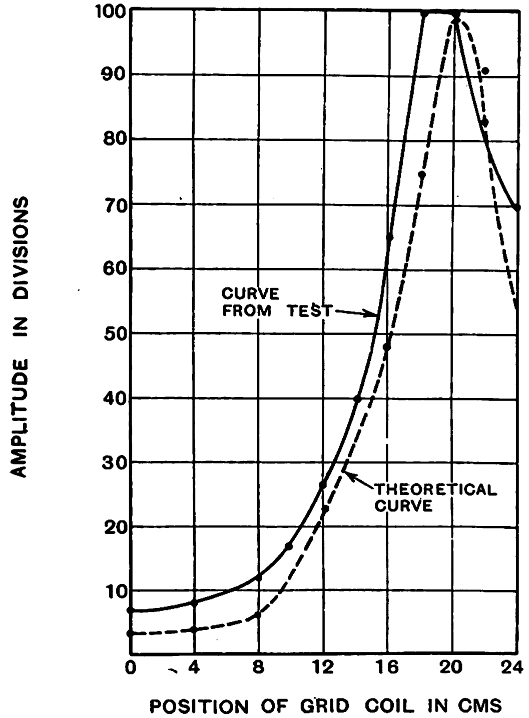


Fig. 11.

In Table VI the values of the effective resistance for different positions of the grid coil are given. Now the strength of the Hartley oscillation will decrease as the rejector resistance increases. It is assumed that in the method employed to measure the strength of the oscillation (see Test 2) the curved position of the detector valve characteristic was employed (this is practically true), then the galvanometer deflection is proportional to the square of the oscillation strength, and therefore proportional to

$$\frac{1}{R^2_{eff}}.$$

In Table VI the column giving the theoretical amplitude was calculated on this basis, the amplitude for 20 cms. being used as the standard. The results are shown in Fig. 11, and from this figure it is seen that the theoretical amplitude changes in practically the same manner as the amplitude measured.

The changes in the frequency and amplitude as the position of the grid coil is varied can therefore be accounted for by considering the alterations in the effective mutual induction between the anode and grid coils.

Explanation of the Results obtained in "Position A."

The measurements of Table V show that the sign of the effective mutual induction is positive from 0.2 cm. to about 16 cms., and negative from about 16 cms. to 24 cms. for "Position A." For the first part it is therefore possible for the anode coil or the Hartley circuit to oscillate, and for the second part it is possible for the grid coil or the Hartley circuit to oscillate. The frequency measurements of Table III show that the anode coil oscillates from 10 cms. to 17 cms. and that the Hartley circuit oscillates from 17 cms. to 24 cms.

The absence of an oscillation from 17 cms. to 21 cms. (see Table III) can be accounted for as follows. In Test 3 it was shown that an oscillation could be detected during this interval if a condenser was connected across the anode and grid of the valve. This oscillation seemed to be confined to the same circuit as the one which oscillated from 24 cms. to 21 cms., *i.e.*, the Hartley circuit (see Table IV). Now if, under normal conditions, the Hartley oscillation stops at 21 cms. owing to the fact that the resistance introduced by the rejector action of the grid coil has become excessive, then the oscillation can only be restarted if this resistance is reduced. This can be accomplished by increasing the difference between the frequency of the Hartley circuit and that of the grid coil. The effect of connecting a condenser across the grid and anode terminals is to reduce the frequency of the Hartley circuit, and hence to reduce the rejector effect of the grid coil. This results in the Hartley circuit commencing to oscillate and continuing to oscillate until 17 cms.

In connection with this interval another point arises. When the Hartley circuit ceases to oscillate at 21 cms. it should be possible for the grid coil to oscillate. Reference to Table V shows that between 20 cms. and 16 cms. the mutual induction changes sign. Now the figures in this table cannot be regarded as very accurate, since to obtain them it has been assumed that the same current flows in the grid and anode coils. Actually these currents will differ owing to the fact that each coil has a self-capacity, and these self-capacities are not of the same value. Therefore it is quite possible that the actual value of the effective mutual induction is less than that given in Table V, and hence it will be too small to maintain an oscillation in the grid coil. It is also possible that the change in the sign of the mutual induction actually takes place before 20 cms., and hence it would be impossible for the grid circuit to oscillate. The positive value of the mutual induction at this point would probably be too small to maintain an oscillation in the anode circuit (see below).

The absence of an oscillation after 10 cms. must now be accounted for. It is probable that the anode circuit ceases to oscillate after 10 cms. because the magnitude of the mutual induction has become too small.

Now when the frequency of the anode circuit is above that of the grid circuit, the greater the difference between these two frequencies the greater is the value of the mutual induction required to maintain an oscillation in the former circuit.*

Therefore, to maintain an oscillation in the anode circuit for the given value of the mutual induction, the frequency of the anode circuit must be reduced.

It was found that if a condenser of about 25 $\mu\mu$F was connected across the anode coil, an oscillation of frequency corresponding to that of the altered anode circuit could be detected. From this we can deduce that the oscillation ceases at 10 cms. because of the low value of the effective mutual induction.

The Hartley circuit does not oscillate after 10 cms. because the value of the effective resistance introduced into its circuit is sufficiently high to stop the Hartley oscillation.

Relation between Parasitic Oscillation and Position of Tapping Point.

So far we have been mainly concerned with the behaviour of the oscillator for a particular tapping position, *i.e.*, 0.8 of "all in." The nature of the oscillations for this position have been considered without reference to the other positions of the tapping point. It was therefore determined to see what effect the other tapping points had on the parasitic oscillations.

The circuit of Test 2 was used, the position of the grid coil was varied, and for each tapping position the presence of a parasitic oscillation was determined by means of the detector shown in Fig. 4.

The tuning circuit of this detector was capable of covering a wide range of frequencies; hence, if an oscillation was present, there was little chance that it would be missed.

TABLE VII.

BEHAVIOUR OF THE PARASITIC OSCILLATIONS.

Position A.

Position of Tapping Point.	Behaviour of the Parasitic Oscillations.	
	Stops at :	Then continues from :
0.9	20.0 cms.	16.0 to 10.2 cms.
0.8	21.0 ,,	17.0 ,, 10.0 ,,
0.7	20.5 ,,	16.5 ,, 9.0 ,,
0.6	20.0 ,,	14.5 ,, 7.2 ,,
0.5	20.4 ,,	
0.4	21.0 ,,	
0.3	21.6 ,,	14.5 ,, 5.8 ,,
0.2	21.7 ,,	15.6 ,, 3.5 ,,
0.1	22.0 ,,	16.2 ,, 1.5 ,,

Position B.

0.9 0.8	Present for all positions of the grid coil.
	Start at :
0.7	24.0 cms. and continue to the end.
0.6	23.0 ,, ,, ,, ,,
0.5	22.8 ,, ,, ,, ,,
0.4	22.2 ,, ,, ,, ,,
0.3	22.0 ,, ,, ,, ,,
0.2	21.5 ,, ,, ,, ,,
0.1	21.4 ,, ,, ,, ,,

---

* *Loc. cit.*, p. 732.

Table VII shows the behaviour of the oscillator for both "Position A" and "Position B" for the different tapping positions. From this table it is seen that in the case of "Position A" there was an interval during which the parasitic oscillation disappeared. Also the parasitic oscillation ceased at some definite point for each position of the tapping point. It is the last point which accounts for the difference in the shape of the curves shown in Fig. 3, for from Table VIII given above it is seen that in the case of each tapping position (excepting 0.1) the parasitic oscillation ceases before the audio oscillation. Hence, as far as the "tap-mutual induction" curve is concerned, the parasitic oscillation will not interfere with the shape of that curve. With reference to the 0.1 tapping position, reference to Table VIII shows that in this case the difference between the actual and theoretical values of the mutual induction is greatest for this position, thus indicating that the presence of the parasitic oscillation does interfere with the audio oscillation.

TABLE VIII.

Position of Tapping Point.	Value of Mutual Induction at which Parasitic Oscillation Stops.	Value of Mutual Induction at which Audio Oscillation Stops.	Theoretical Value of Mutual Induction required.
	Henries.	Henries.	Henries.
0.9	0.053	0.052	0.049
0.8	0.060	0.048	0.045
0.7	0.046	0.043	0.040
0.6	0.054	0.039	0.036
0.5	0.136	0.034	0.032
0.4	0.138	0.031	0.029
0.3	0.045	0.029	0.027
0.2	0.033	0.0325	0.029
0.1	0.025	0.057	0.040

The theoretical value of the Mutual Induction required was obtained from the formula :—

$$M = \frac{RRaC}{mb} + bL$$

where b = position of tapping point and R, C and L refer to the resistance, capacity and inductance, respectively, of the audio circuit.

From Table VII it is seen that in the case of "Position B" the parasitic oscillation once started continues for all positions of the grid coil and for all tapping positions. Therefore the parasitic oscillations will interfere with the shape of the "tap-mutual induction" curve.

Effect of Preventing the Parasitic Oscillation in the Case of "Position B."

It has been shown that the parasitic oscillation is confined to a Hartley circuit in the case of "Position B." Now this oscillation can be prevented by the insertion of a suitable condenser and resistance in its circuit. The value of the condenser and resistance required can be calculated as follows :—

The condition for the maintenance of oscillations in a Hartley circuit is given by :—

$$CRRa(L_1+L_2\pm 2M) < (L_1 \pm M)\,[m(L_2 \pm M)-(L_1 \pm M)]$$

Where L_1 = inductance of anode coil = 0.077 henry.
L_2 = inductance of grid coil = 0.08 henry.
M = mutual induction between the coils.
C = capacity of Hartley circuit.
R = resistance of Hartley circuit.
Ra = internal resistance of the valve = 22,000 ohms.
m = amplification factor of the valve = 9 ohms.

Therefore, for a given valve and a given L_1, L_2 and M, the Hartley oscillation can be prevented by increasing C, R, or their product.

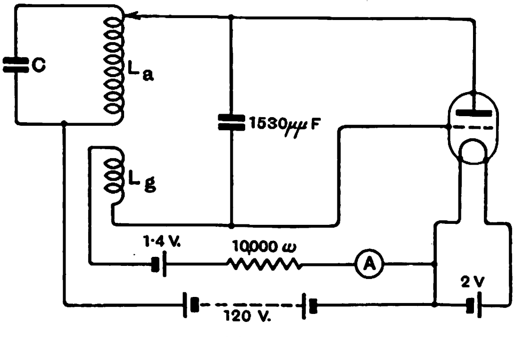


Fig. 12.

For a capacity of 1,530 μμF and zero mutual induction, the resistance required to stop the Hartley oscillation is 10,000 ohms.

The circuit of Fig. 1 was therefore used with the addition of a 10,000 ohms non-inductive resistance which was placed in the grid circuit, and a condenser of 1,530 $\mu\mu$F placed between the grid and anode. These modifications are shown in Fig. 12.

The curve marked "Position B" in Fig. 13 shows the effect of adding this resistance and condenser.

In addition it was found that for all values of the mutual induction below that required to produce audio oscillations no deflection was obtained in the grid ammeter, thus indicating that there was no parasitic oscillation present.

Conclusions.

1. The difference in the behaviour of the oscillator for "Position A" and "Position B" is due to the presence of parasitic oscillations.

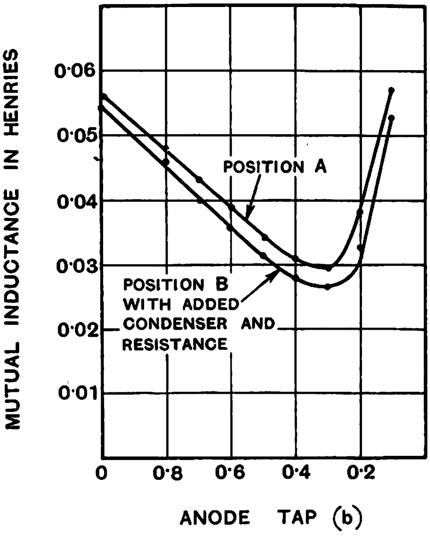


Fig. 13.

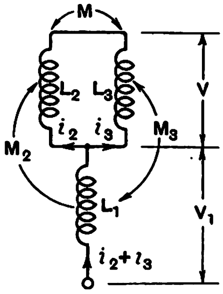
2. In the case of "Position A" these oscillations are confined to the anode circuit for some positions of the grid coil, and to a Hartley circuit for other positions of the grid coil. Also the parasitic oscillations stop at some definite position of the grid coil for each tapping point. In all cases (except the 0.1 tapping point) the parasitic oscillation stops before the legitimate audio oscillation.

3. In the case of "Position B" the Hartley circuit oscillates for all positions of the grid coil and it is not until this oscillation is prevented by the addition of a suitable resistance and condenser that the "tap-mutual induction" curve becomes the same for this position as for "Position A."

APPENDIX I.

To determine the Effective Mutual Induction between the Anode and Grid Coils.

The figure given below shows the arrangement of the anode and grid coils when they are connected in series.



In this figure :

L_2 and L_3 = inductance of the respective portions of the anode coils separated by the anode tap.
L_3 = inductance of grid coil.
M = Mutual induction between the portions of the anode coil separated by the anode tap.
M_2 = Mutual induction between the grid coil and L_2.
M_3 = Mutual induction between the grid coil and L_3.

The signs of all the quantities are assumed positive.

Assume that a voltage V is applied to the anode coil, and that a voltage V_1 is applied to the grid coil, and let the resulting currents be as shown in the diagram.

Neglecting resistance, we have for the anode coil :—

$$V-j\omega M_2\,(i_2+i_3)-j\omega M i_3=j\omega L_2 i_2 \quad .. \quad 1$$

$$V-j\omega M_3\,(i_2+i_3)-j\omega M i_2=j\omega L_3 i_3 \quad .. \quad 2$$

Adding 1 and 2, we have :—

$$2V=j\omega[(i_2+i_3)(M+M_2+M_3)+L_2 i_2+L_3 i_3] \quad .. \quad 3$$

Subtracting 2 from 1, we have :—

$$i_2(M-M_2+M_3-L_2)=i_3(M+M_2-M_3-L_3) \quad .. \quad 4$$

∴ from 3 and 4 we have :—

$$\frac{V}{i_2+i_3}=j\omega\left[\frac{M_3(M-L_2)+M_2(M-L_3)+M^2-L_2L_3}{2M-L_2-L_3}\right]$$

∴ the effective inductance of the anode coil is given by :—

$$La_{eff}=\frac{M_3(L_2-M)+M_2(L_3-M)-M^2+L_2L_3}{L_2+L_3-2M}$$

$$=\frac{L_2L_3}{L_2+L_3-2M}+\frac{M_3(L_2-M)+M_2(L_3-M)-M^2}{L_2+L_3-2M} \quad .. \quad 5$$

Now $\dfrac{L_2L_3}{L_2+L_3-2M}$ is the normal inductance of L_2 and L_3 in parallel. Therefore expression 5 may be written :—

$$La_{eff} = La + Mg \quad .. \quad .. \quad 6$$

Consider now the grid coil. As before :—

$$V'-j\omega(M_2i_2+M_3i_3)=j\omega L_1(i_2+i_3) \quad .. \quad 7$$

From 4 and 7 we have :—

$$\frac{V'}{L_2+L_3}=j\omega\left[\frac{L_1(L_2+L_3-2M)+M_2(L_3-M)+M_3(L_2-M)-(M_2-M_3)^2}{L_2+L_3-2M}\right]$$

$\therefore$

$$Lg_{eff}=L_1+\frac{M_2(L_3-M)+M_3(L_2-M)-(M_2-M_3)^2}{L_2+L_3-2M} \quad 8$$

which may be written :—

$$Lg_{eff} = Lg + Mg \quad .. \quad .. \quad .. \quad 9$$

From 6 and 9 :—

$$La_{eff}+Lg_{eff}=La+Lg+2\left(\frac{Ma+Mg}{2}\right)$$

$\therefore$ the effective mutual induction between the anode and grid coils is given by :—

$$M_{eff}=\frac{Ma+Mg}{2}$$

$$=\frac{M_2(L_3-M)+M_3(L_2-M)}{L_2+L_3-2M}-\left[\frac{M^2+(M_2-M_3)^2}{2(L_2+L_3-2M)}\right]$$

In the oscillator under consideration M_2 is negative (see p. 141)

$$\therefore M_{eff}=\frac{2[M_3(L_2-M)-M_2(L_3-M)]-M^2-(M_2+M_3)^2}{L_2+L_3-2M}$$

also $$Ma=\frac{M_3(L_2-M)-M_2(L_3-M)-M^2}{L_2+L_3-2M}$$

and $$Mg=\frac{M_3(L_2-M)-M_2(L_3-M)-(M_2+M_3)^2}{L_2+L_3-2M}$$

ERRATA.

"THE STABILITY OF THE TUNED-GRID TUNED-PLATE H.F. AMPLIFIER."

Equation 19 should read :—

$$k/H = g[1 - G\cdot\sigma_v/g]/G^2\cdot C_0\cdot\Omega \quad .. \quad (19)$$

and Equation 21 should read :—

$$[k/H]\ [C_0\cdot\Omega\cdot g/\sigma_v{}^2] = [1 - G\cdot\sigma_r/g]\ [g/G\cdot\sigma_r]^2 \quad .. \quad (21)$$

What is the Correct Characteristic for a Variable Condenser?

By Lieut.-Col. K. E. Edgeworth, D.S.O., M.C., A.M.I.E.E.

THEORETICALLY the resonant frequency of a tuned circuit may be adjusted either by varying the capacity or by varying the inductance, but for practical reasons the employment of variable condensers in wireless receivers is almost universal.

In the earliest variable condensers the shape of the moving plates was semi-circular, so that the capacity in circuit was approximately proportional to the angular movement of the dial over the greater part of the working range. Of recent years condensers have been designed so as to give other characteristics, and the shape of the plates has been varied accordingly. There have been plates designed to give a straight line relationship between wavelength and angular movement, or between frequency and angular movement, and plates giving an exponential characteristic, and plates giving no obvious characteristic at all.

With this variety of types to choose from it is natural that the user should ask himself what type is really the best, and the object of the present paper is to assist him in arriving at a correct answer.

The dial of a wireless receiver is usually calibrated in degrees, and the user of the instrument is expected to interpret the readings by means of a calibration chart. It is to be hoped, however, that this very cumbrous expedient will soon be abolished. There is no serious difficulty in calibrating the dials of a receiver directly in metres, and the advantages of doing so are obvious.

The construction and use of a calibration chart is facilitated if the characteristic which is being plotted is approximately linear. Not only are fewer calibration points required, but the curve itself will possess a higher degree of accuracy.

In Europe the metre is the unit which is most commonly employed, and it is therefore convenient to use condensers having a straight line wavelength characteristic. For the same reason condensers with a straight line frequency characteristic would be convenient in America. The argument has not very much force, however, since it is open to wireless engineers to describe transmissions by means of either unit.

The allotment to transmitting stations is governed by the need for avoiding interference, and the interval between the wavelengths allotted is usually fixed at some definite number of cycles, say, 20,000 cycles for telephony, and 2,000 cycles for telegraphy.

When stations are tuned in on a receiver there is usually a tendency for the stations to crowd together at the shorter wavelengths, the intervals between stations being somewhat as shown in Table I.

TABLE I.

Kilo-cycles.	Metres.	Interval between Stations.		
		A.	*B.*	*C.*
1,200	250.0	1.85°	2.1°	4.6°
1,180	254.2			
560	535.7	12.4°	9.9°	4.6°
540	555.5			

A. Semi-circular plates.
B. Straight line wavelength.
C. Straight line frequency.

It is argued on behalf of the straight line frequency condenser that various transmitting stations should be equally spaced on the dial of the receiver, and it will be observed that the straight line frequency condenser possesses this characteristic.

The validity of this contention is open to question, however, and it is desirable to look into the matter a little more closely.

The fundamental purpose of the variable condenser is to enable the receiver to be adjusted in such a manner that the distant station is received at maximum strength, and it is necessary that the instrument should be capable of being adjusted to a certain specified degree of accuracy at all points of the scale.

The degree of accuracy required may be defined by saying that it must be possible to adjust the condenser so that the signals are within 90 per cent. of maximum strength, or any other desired percentage may be selected. For our present purpose it is sufficient to agree that some standard is desirable, but it is not necessary to fix any particular standard except for purposes of illustration.

The ease with which the receiver can be adjusted depends upon the selectivity, the size of the dial, the ratio of the gearing (if any), and so on; but it is evident that any desired standard of accuracy can be most readily secured when the facilities for accurate adjustment are equal at all points of the scale.

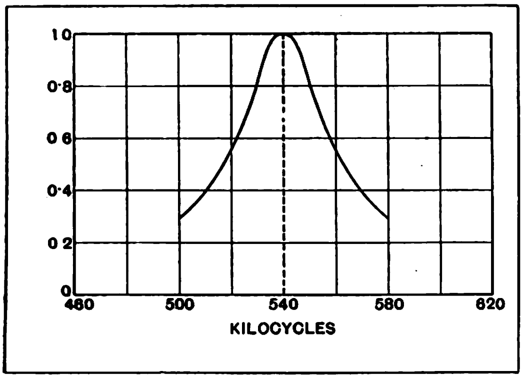


Fig. 1.—*Selectivity at 550 metres.*

The question of selectivity has been analysed in *E.W. & W.E.* in a paper by P. K. Turner,* and the analysis shows that the selectivity of the tuned circuit varies inversely as the tuning capacity or nearly so.

This is illustrated in Figs. 1 and 2, which show the selectivity of the same amplifier at 550 and at 250 metres respectively. With a multi-stage amplifier the curves would be different, but the relative selectivity at the two different settings would remain unchanged. In either case the instrument is more than four times as selective at 550 metres as it is at 250 metres.

Assume that the receiver comprises a single tuned circuit having a tuning capacity of 500$\mu\mu$F. at 555.5 metres, and that the valve has an anode A.C. resistance of 20,000 ohms. Then the error in setting which will reduce the desired signal to 90 per cent. of the maximum is given in Table II.

TABLE II.

Kilo-cycles.	Metres.	Allowable Error in Tuning.		
		A.	*B.*	*C.*
1,200	250.0	3.1°	4.1°	4.5°
540	555.5	3.1°	2.3°	1.0°

A. Semi-circular plates.
B. Straight line wavelength.
C. Straight line frequency.

At 555 metres it will be observed that the adjustment on the straight line frequency condenser is more than twice as critical as it is on the straight line wavelength type and three times as critical as it is on the condenser with semi-circular plates. Judged according to this standard the condenser with the semi-circular plates is the best and the straight line frequency condenser is the worst.

In order to reach a perfectly logical conclusion it would be necessary to estimate the relative importance of equal spacing of stations on the one hand and equal facility of adjustment on the other, and this seems hardly possible. It is interesting to observe, however, that the use of gearing increases the ease of adjustment and makes it less necessary to provide uniformity in this respect. On the other hand it may be argued that the provision of a large dial accompanied

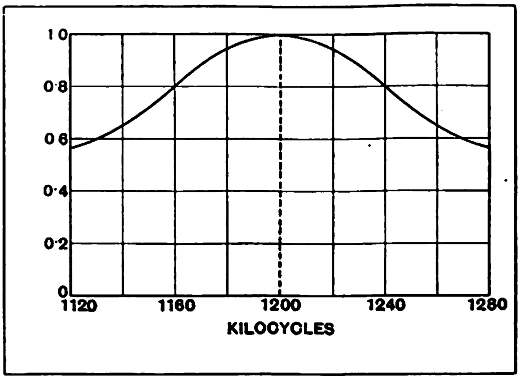


Fig. 2.—*Selectivity at 250 metres.*

---

* *E.W. & W.E.*, October, 1925.

by uniform or nearly uniform facility of adjustment may render the use of gearing unnecessary.

The usual solution to a problem of this sort is a compromise, and attention is naturally directed to the straight line wavelength condenser which is seen to occupy an intermediate position between the other two.

The position may be summed up by saying that the straight line wavelength condenser possesses the following advantages:

(i) It avoids the very close crowding of stations which occurs on short wavelengths with condensers having semi-circular plates.

(ii) It avoids the very critical tuning adjustment which is necessary on long wavelengths with condensers having a straight line frequency characteristic.

(iii) In Europe, where the unit employed is the metre, the calibration curve is a straight line, and the construction of instruments reading directly in metres is facilitated.

It is perhaps desirable to add a warning that many of the condensers advertised as square law condensers do not give a straight line relationship between wavelength and angular movement. The correct curve, to a first approximation, has been given by W. H. F. Griffiths in *E.W. & W.E.* for January, 1926.

Book Reviews.

THE PROPAGATION OF RADIO WAVES ALONG THE SURFACE OF THE EARTH AND IN THE ATMOSPHERE. By P. O. Pedersen. Pp. 244+19. Published by G. E. C. Gad, Vimmelskaftet 32, Copenhagen. 15 Kr.

This is a most important publication. Although written by a Dane and printed and published in Denmark, it is written in perfect English. Anyone acquainted with Prof. Pedersen's work on the Poulsen Arc and other subjects will expect to find the subject dealt with in a thoroughly scientific and accurate manner. Their expectations will be amply fulfilled, for the book represents a masterly analysis of the subject. It is dedicated "to my friend Dr. Valdemar Poulsen who twenty years ago and first of all demonstrated perfect radio telephony." The book is really in two volumes, as a number of curves and nomograms are bound separately in a 19-page appendix. The book is divided into 11 chapters and each chapter is subdivided into a number of sections, each section dealing with a definite subject and giving references to the various authorities on that subject. The author has attempted to give a connected physical theory of radio wave propagation; as he says in the preface, "the main basis of such a theory must be the state of ionisation and the electrical and optical properties of the atmosphere and it has therefore been necessary to discuss such questions as air pressure at high altitudes, mean values of free path for the electrons and ions, sources of radiation, etc." In working out the necessary formulæ for the influence of electrons and ions, and of the magnetic field of the earth on the propagation of waves, the author says that he has not aimed at mathematical elegance and brevity but has tried to carry out the calculations in such a way that the physical aspect of the question is never lost sight of.

The work is quite up to date, although, as the author says, the development has been so rapid that many of the most important papers bearing on the subject have appeared during the printing of the book. We noticed a reference to a paper which appeared in *E.W. & W.E.* as recently as May, 1927, and all the recent work of Appleton and Barnett, Breit and Tuve and others is discussed in detail.

It is a book which no one interested in the subject can afford to be without.

THE INTERACTION OF PURE SCIENTIFIC RESEARCH AND ELECTRICAL ENGINEERING PRACTICE. By Prof. J. A. Fleming, F.R.S. Pp. x.+235, with 64 Figs. Constable. 15s.

"In the following pages we shall attempt to show the manner in which the electrical industry is based essentially on, and advanced by, pure scientific research, and also the manner in which technology repays its debt to pure science by providing new materials or appliances or larger opportunities for experiment, and so advances our knowledge of the processes at work in Nature." This quotation from the introduction indicates the object of the book, which is an expansion of a course of eight public lectures delivered by the author in the spring of 1926. "As it would be difficult to deal with the subject apart from specific instances, the objects in view can best be attained by discussing a limited number of branches or special departments of electrical engineering and endeavouring to show in each and all of them that technical advances have, in general, been due to previous or contemporary scientific investigations, which have, at the time they were made, no other aim than that of a disinterested advancement of scientific knowledge." The eight lectures are represented by eight chapters dealing with: (1) insulation and conduction, (2) ferromagnetism, (3) thermionics, (4) glow and arc discharges, (5) telephony, (6) surges and pressure rises, (7) electrochemistry and metallurgy, (8) electrical measurements. The book is what one would expect from a lecturer and writer of Dr. Fleming's calibre and reflects his long and intimate acquaintance with the various branches of electrical science. A reader with a certain amount of scientific knowledge will obtain a very good idea of the history of the various branches of electrical engineering dealt with in the book, and it can be unreservedly recommended to any reader of *E.W. & W.E.* The chapter on ferromagnetism includes a very interesting illustrated account of Mr. Mordey's wonderful and puzzling research on the separating of magnetic ores by means of alternating currents. In the chapter on thermionics we think that the author might have been a little more generous in his references to Dr. de Forest's share in the invention of the three-electrode valve. The chapter on glow and arc discharge describes the various vacuum tubes now so popular for illuminated signs and also the mercury arc rectifiers now so largely used for power purposes. Under surges and pressure rises the author describes the various devices for protecting apparatus from their effects. The subject of electrochemistry and electrometallurgy provides many examples of the application of research to commercial problems, various electric furnaces being described. The final chapter describes the development of accurate units and standards of measurement of the various magnitudes involved in electrical engineering, the most recent piece of pure science to be harnessed being the piezoelectric effect. Prof. Fleming is to be congratulated on making these lectures accessible to those who were denied the pleasure of hearing them.

A Study of Radio Direction Finding—Special Report No. 5 of the Radio Research Board. Prepared by R. L. Smith-Rose. 37 pp. Published by H.M. Stationery Office. Price 1s. 6d.

Several reports have already been issued dealing with the work of the Committee on Directional Wireless. The present one summarises the progress made during the last five years and gives a comprehensive survey of the subject. A theoretical discussion is also given, indicating the contribution which the study of direction finding has made to the solution of the problem of wave propagation. On the practical side one of the most important results of the research was the discovery at a late stage that Adcock had patented a system in 1919 which completely eliminates the night effect and gives practically correct bearings under all circumstances. The report concludes with the statement that the practical development of this system is now being pursued. A bibliography gives 60 references to publications dealing with direction finding. Anyone wishing to obtain a good knowledge of the history and present position of the subject could not do better than study this report.

The Thermionic Valve. By Fred Goddard. Pp. 192. Mills & Boon. Price 3s. 6d. net.

This is a popular non-mathematical book in which the valve is described in clear, simple language. After an introduction, the manufacture of a valve is described step by step, then the action of a valve in detection and amplification; this is followed by a description of the ways in which valves are used in different circuits. The last 50 pages are devoted to a number of valve circuit diagrams. On the whole, the book is clearly written, but it is not always so clear as it might be. We wonder if there is any evidence that the magnesium mirror on the inside of the bulb absorbs gas liberated during the life of the valve. It may be so. On page 34 the temperature coefficient of resistance of tungsten is given as 0.400; it should be 0.004. "Anode impedance" is always employed and designated by "*R*" in spite of a table giving "*Z*" as the symbol for impedance. The statement on page 75 that "the usual method of producing a valve with a high M value is to set the grid . . . near the filament and the anode a comparatively long distance away. The effect of this facilitates filament current flow while retarding anode current flow" is very strange. How it can affect the filament current flow is difficult to understand. On page 77 the numerical example is far from clear, while on page 80 the statement that "the number of electrons emitted per second is proportionate to the temperature of the filament—in other words, the amount of current passing through it" makes one wonder what meaning the author attaches to the word "proportionate." The same applies to the term "overall efficiency" on page 91, where we are told that "the best valves to procure are those which possess the highest overall efficiency. This is a combination of several efficiencies. The most important of these are (1) thermal efficiency, (2) characteristic efficiency, (3) life efficiency, (4) microphonic efficiency." A useful word is "efficiency." We will conclude with a good example of Mr. Goddard's style: "Signals launched into space at a point round the periphery of the earth antipodal to the receiver are constantly recorded, and even in the attenuated atmosphere which some of our high-climbing aviators have reached the thermionic valve has proved susceptible to impulses from the earth over hundreds of miles."

Les Filtres Électriques: L'Alimentation des Postes Récepteurs. By M. Veaux. Pp. 242 with 227 Figs. Librairie del enseignement technique. Paris.

A better title would be "The power supply to receivers, with special reference to filters or smoothing devices." Of the four chapters, the first is devoted to primary cells and secondary batteries; the second to the theory of filters; the third to battery charging devices; and the last to the supply of filament and anode current from D.C. and A.C. mains.

The treatment of the subject of filters is very clear, with just sufficient mathematics to enable one to design a filter of given approximate characteristics, without going into the more complex aspects of the question. For battery charging from A.C. mains various rectifiers are described, including gas, electrolytes, colloidal silver and mercury vapour, as well as several of the mechanical type; we could not find any reference to the copper oxide type. The final chapter deals with the various methods of supplying anode and filament currents from D.C. and A.C. mains. The book is clearly written and numerical values are given in nearly every case considered. It is a book which can be recommended.

G.W.O.H.

The Effect of Weather Conditions on Long-Distance Reception.

By S. K. Lewer.

Introduction.

IT is intended in this paper to give an outline of the further investigations carried out along the lines of the experiments described in the writer's "Notes on the Conditions Governing Transatlantic Reception."[1] After the end of 1925 several experimenters commenced systematic observations on long-distance reception and its variations, in an attempt to connect these variations with changes in the weather. The general practice was to observe the changes in the *local* atmospheric pressure, temperature, etc. The writer compared the curve showing the variations in the *local* atmospheric pressure for every day during 1924 and 1925 with the curve showing the variations in the conditions for transatlantic reception, as obtained from the log-books. For isolated periods of three or four weeks the two curves took the same shape, but the resemblance was too vague to allow any definite conclusions to be formed. Attempts to connect the variations with the changes in the temperature, cloud and wind, have similarly proved fruitless. In fact, there is every reason to believe that the changes in local conditions are of no interest whatever, when dealing with long-distance reception. The connection, if any, must be looked for in the changes in the space between the transmitting and receiving stations. We have evidence,[2] but very unreliable evidence, of an apparent connection between reception conditions and the phases of the moon. It must be borne in mind, however, that if the experiments dealing with the subject in general are to be of any practical or theoretical use, particularly in connection with the phases of the moon, they must be carried out over long-continued periods. The evidence drawn from experiments covering periods of one or two months is not sufficiently reliable. The period must be long enough for generalisations to be made. While dealing with the effect of the moon, the writer wishes to repeat here that from all the experiments he has made he has not found any connection between the phases of the moon and reception conditions. From the experiments it was found that the moon may vary in coincidence with the reception conditions for about one month, but later in the year it may be completely out of step. This is not evidence to show that the moon has no effect on reception: its effect, if any, may be masked at certain periods by some other more potent factor. The moon probably affects reception by the tidal movements of the atmosphere which would result in changes in the refracting and reflecting properties of the ionised regions.

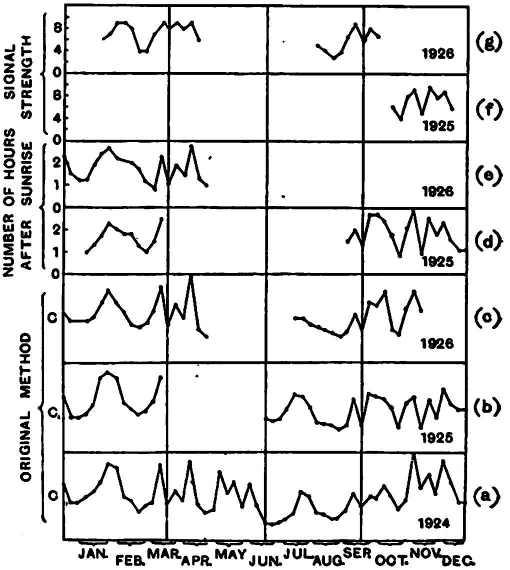


Fig. 1

Variations in the Reception Conditions.

As stated in the article mentioned above,[1] the curve showing the variations in radio conditions (for transatlantic reception) throughout the year 1924 was followed in the first part of 1925 by a curve coinciding in shape with the curve for 1924. Much will be said about this curve, so it is repeated here for convenience in comparing it with the other curves to be described (see Fig. 1 (a)).

---

[1] *E. W. & W.E.*, Dec., 1925, p. 958.

[2] *E.W. & W.E.*, July, 1926, p. 429.

For the sake of brevity, the measure of conditions for long-distance reception will, for present purposes, be called *C*; that is to say, when long-distance reception is particularly good the value of *C* is high, and conversely, when conditions are poor *C* is low.

As the result of continued investigations it can be said with some certainty that the curve is similar every year, that is, the periods of good and bad conditions recur in the same sequence every year. The considerations by which this conclusion was reached will be given later. From Fig. 1 (a) it appears that the second half of the curve is similar (in the fluctuations up and down, but not in the absolute values of *C*) to the first part of the curve; in other words, the curve is repeated every six months. However, the writer does not wish to lay too much stress on this apparent six-monthly repetition. It may be a mere accident, an error incurred in some way, or it may be an aid in solving these problems. On considering the *annual* repetitions it appears that the variations are caused by some solar influence, direct or indirect (assuming that the position of the earth relative to the solar system has no effect on the value of *C*). The sun may be held responsible for the usual gradual change in *C* from summer to winter. There is no doubt about this. The very much more abrupt changes represented in the curve are very irregular throughout each half of the year, and it is improbable that these changes are caused *directly* by the sun. More probably the changes are due to some complex cyclical change. This cycle of changes, whatever its nature may be, and however complex, must be repeated annually. Other variable factors, quite independent of the sun, may be responsible for the particularly low and high values of *C*. It must be pointed out here that although the curve takes the same *shape* every year, in the sense that the maxima and minima of one year coincide as regards the time of the year with the maxima and minima of any other year, yet the respective values of *C* may not be the same in any two years. In practice the determination of the absolute value of *C* is much more difficult than the determination of the changes in the value of *C*, or, in other words, it is more difficult to say whether the conditions on any given night are good or bad for the time of the year, than it is to say, whether the conditions are improving or deteriorating. Hence, too much attention must not be paid to the actual values of *C*. If the exceptionally high and low values of *C* are due to experimental errors, then it is possible that there are *no* factors which are *independent* of the sun, that is, that all the variations are caused (directly or indirectly) by the sun. At any rate, in this paper only the changes which are repeated annually will be dealt with, and irregular effects, if any, will be disregarded. Before proceeding further it would be advisable to give the detailed evidence the writer has for believing that the changes in *C* represented by the curve in Fig. 1 (a) are repeated annually.

Evidence for Annual Repetition of Changes in *C*.

For the greater part of 1925 the writer continued observations on the signals from amateurs in North America and Brazil. The observations consisted mainly in determining the number of stations audible in a given period of time (generally one hour). This was the original method used by the writer in drawing the curve in Fig. 1 (a). The curve obtained for 1925 by this method is shown in Fig. 1 (b). It is remarkably similar to the curve for 1924, the only real difference being that on one or two occasions a maximum or minimum value of *C* on one curve would occur a week before or behind the corresponding maximum or minimum on the other curve. The corresponding values of *C* were not always the same, but, as explained above, it is not the *absolute* values of *C* but the *changes* of *C* which are important.

Another method of observation used by the writer was the determination of the length of time after sunrise of the " moment " when the signals at last became inaudible. This "moment" was generally of about 10 minutes' duration, and yielded fairly definite results, since the length of time after sunrise was, on the average, about two hours. It may be seen that the curve obtained by this checked very closely with the other curves. See Fig 1 (d). The writer outlined this method in the description of the original experiments[1] and offered four objections to it, but in the light of further evidence it appears to be a fairly satisfactory and convenient method.

A third method was used for a short period: this was the determination of the signal-strength of one particular station at the same time each night. The station in this case was WIZ, the R.C.A. station at New Brunswick, working with high power on 43.02 metres. The signal-strength was estimated aurally by the familiar "R" standard. This is usually considered to be a very unsatisfactory method, but as the signal-strength variation was large (from R3 to R9) the results were not regarded as being quite useless. The curve produced is shown in Fig. 1 (f), and it can be seen that as far as it continues it checks closely with all of the other curves. The "shunted-phones" method of measuring the signal-strength was given a trial, but, due to various causes, it was found to be no more accurate than the method of estimation by the "R" standard. Since the station was sending in morse, all ballistic or dead-beat galvanometers were out of the question; in either case the deflection would depend upon the speed of sending. These methods were continued to some extent during a part of 1926, and the curves obtained all checked with the original curve with a considerable degree of accuracy. The curves for 1926 are shown in Fig. 1 (c, e, g). These, and the 1925 curves, correspond to the wavelength band of 35-40 metres, whereas the 1924 curves correspond to the wavelength bands of 150–200, 100–110, and 35–40 metres. Here are several curves obtained by three different independent methods. Apart from occasional discrepancies, all the curves are of the same shape, indicating maximum and minimum values of C on approximately the same dates in three successive years. The evidence given here is considered to be sufficient to show that the changes are repeated annually.

Possible Causes of the Variations.

It is very interesting to note that similar variations in C for very long waves have been observed. L. W. Austin has produced curves[3] showing the variations during 1922-3-4 in the field-strength received in North America from LY, Lafayette, France, the wavelength being 18,900 metres. Only monthly changes are given, but for the greater part of the three years the curves correspond to the curve shown in Fig. 1 (a) which was drawn from observations on waves of under 200 metres. The extent of the variations in the field-strength observed on the 18,900 metre wave was as much as 50 per cent. reduction from the maximum during some months. The characteristics of these long waves are much more stable than those of waves of less than, say, 300 metres. If these long waves are affected throughout the year in a manner similar to that in which the short waves are affected it may be assumed that the cause is the same in each case. The percentage variations in field-strength in the two cases do not differ by a very large figure. Now there must be very drastic changes in this factor to cause large changes in C for long waves, whereas, since the changes in C for short waves are so very frequent and variable, it seems that even slight changes in this factor cause large changes in C for short waves. This is an important point.

It has been shown mathematically by Eccles[4] and Larmor[5] and others that the long waves are returned from the ionised medium at lower altitudes than the shorter waves. Let the height be H for the short waves (this is the *effective* height since short waves are refracted over, not reflected) and h for the long waves, which are truly reflected.[6] Then the relatively drastic changes referred to above in the case of long waves must occur in regions below the height h. It is unreasonable to suppose that the path of the wave will be influenced by any changes which occur only in the medium *above* the path. The changes in this factor need only be slight in the case of short waves at a height H, that is, at a height above h. The conclusion to be drawn is that the magnitude of the changes for which we are looking decreases as the height above the earth increases. Now there are several things which vary by smaller amounts as the altitude increases. Probably the most important of these is the intensity of ionisation, about which, unfortunately, very little is known. The temperature varies most at ground level, and is constant at about 200° abs. in the isothermal layer which extends from about 10 kilometres to about 55 kilometres above the earth's surface. Above this layer the temperature rises to about 300° abs. at 150 kilometres (Lindemann and Dobson). Precisely what happens to the temperature above the isothermal layer is at present a subject of much discussion. There seems to be no definite evidence relating to winds in the upper atmosphere. According to some investigators, the atmospheric pressure at an altitude of 20 kilometres is practically constant throughout the year, but from the results of some experiments[7] commenced in 1909 there appears to be a maximum deviation of about 8 per cent. from the mean pressure at an altitude of 20 kilometres throughout the year, which is about twice the deviation from the mean pressure at sea-level. The evidence, however, is far from being conclusive, and the deviation at 20 kilometres may be much less than 8 per cent., and still less at greater altitudes. These questions of pressure and temperature, and those of humidity, density, chemical constitution, intensity of ionisation, etc., at high altitudes are for the meteorologists and astrophysicists to settle, and, unfortunately, at present there seem to be no definite conclusions.

---

[1] *E.W. & W.E.*, Dec., 1925, p. 958.

[3] L. W. Austin, *Proc. I.R.E.*, June, 1925.

[4] W. H. Eccles, *Proc. Roy. Soc.* (87A), 79, 1912.

[5] J. Larmor, *Phil. Mag.*, Vol. 48, 1924.

[6] E. V. Appleton, *Nature*, 9th Oct., 1926.

In comparing long and short waves, it must not be forgotten that the long waves are truly reflected from the medium, since the change in conductivity with height is sharp compared with the wavelength, whereas the short waves are refracted from the medium. Ordinary reflection of short waves may occur if, for some reason, there happens to be an exceptionally sharp change in the conductivity with height. The distinction between reflection and refraction adds one more difficulty to the problem. The variable factors may influence the reflection without affecting the refraction, or *vice versa*, or they may influence one more than the other.

Here is an effect which appears to vary, for both long and short waves, in the same way during the year (and perhaps every year), and to have a comparatively greater influence on long waves than on short waves Is this because long waves are *reflected* and short waves *refracted ?* Or is it because the short waves penetrate to a higher altitude than the long waves ? The writer makes no attempt to answer these questions, but offers them as lines for further investigation.

It should be noted that the monthly changes in the long waves are of the same magnitude as the monthly changes in the short waves, but the diurnal changes in the long waves[8] are much smaller than the diurnal changes in the short waves: it has been shown that on a wavelength of about 17,000 metres the signals are practically constant throughout the day and night. An investigation of this effect might possibly throw some light on the problem.

Leaving the subject of long waves, we have the suggestion by Pickard, and Nichols and Schelling[9], that diffraction effects may occur on short waves due to space irregularities in the medium. These effects would be more frequent, and of greater importance, as the wavelength decreases, since smaller irregularities in the medium are more likely to occur than large irregularities. Diffraction effects may occur more largely at one period of the year than at another period, but at present it seems impossible to investigate them. At any rate, the diffraction would probably be very erratic (possibly accounting for fading and audio-frequency distortion), and it may reasonably be set down as one of the *irregular* factors.

The vertical motion of masses of heated air has been suggested by Baeumler[10] as producing "electrical turbidity" of the atmosphere, resulting in a weakening of signal-strength during the day. This "turbidity" would appear to be another of the irregular factors, since the motion of the air is governed by such a large number of factors that any regularities would probably disappear. It is interesting to note that in the same paper Baeumler gives reasons for considering the *night* conditions as *normal*, and the *day* conditions as *abnormal*, with regard to the propagation of electromagnetic waves. This is the opposite of the present general opinion. It is an important point, as it raises the question of the validity of any conclusions drawn from experiments made during the day. All the experiments made by the writer have necessarily been carried out under night conditions.

---

[7] L. H. G. Dines, *Meteorological Mag.*, Sept., 1926, p. 190.

[8] Espenschied, Anderson, Bailey, *Proc. I.R.E.*, Feb., 1926.

[9] Nichols and Schelling, *Bell Syst. Tech. Journ.*, April, 1925.

[10] M. Baeumler, *Proc. I.R.E.*, Feb., 1925.

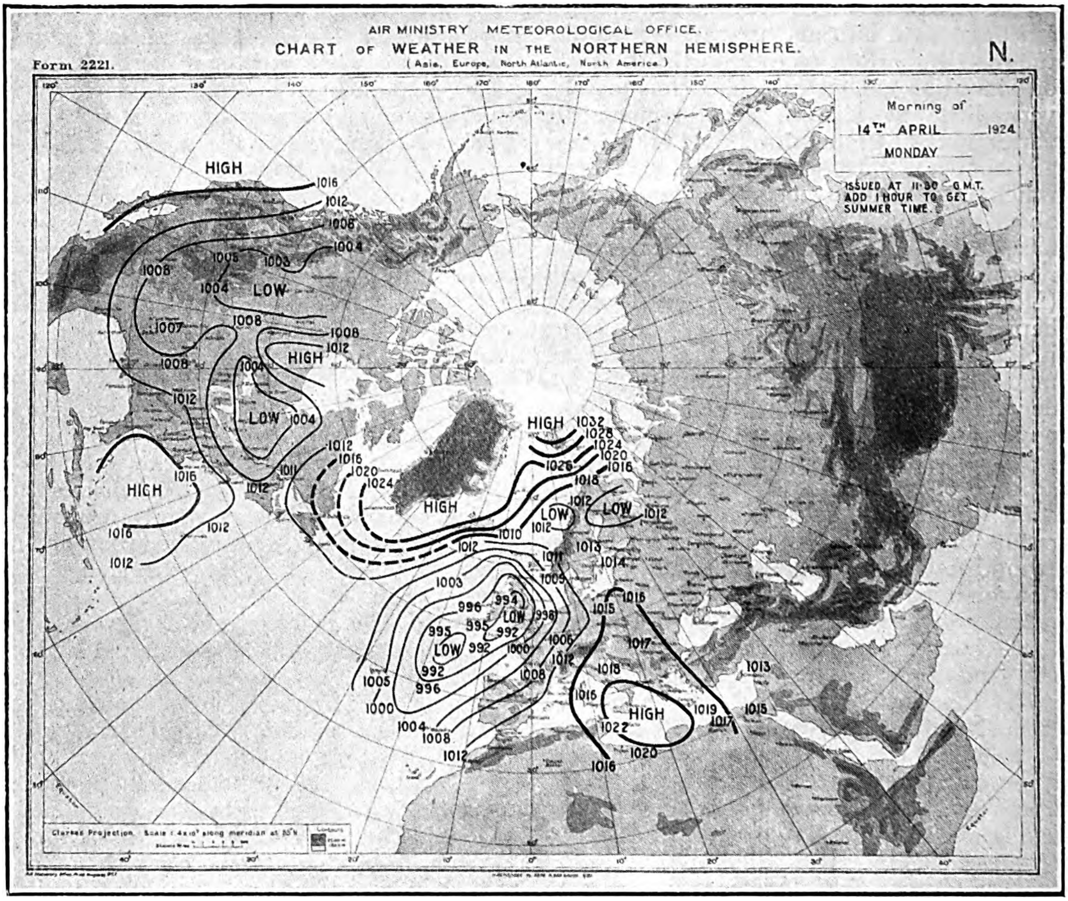

AIR MINISTRY METEOROLOGICAL OFFICE.
CHART OF WEATHER IN THE NORTHERN HEMISPHERE.
(Asia, Europe, North Atlantic, North America.)
Form 2221.
N.
Morning of 14TH APRIL 1924
MONDAY
ISSUED AT 11.30 G.M.T. ADD 1 HOUR TO GET SUMMER TIME.
HIGH
LOW
HIGH
LOW
HIGH
HIGH
HIGH
LOW
LOW
LOW
HIGH
1016
1012
1008
1004
1007
1011
1020
1024
1028
1032
1026
1018
1010
1003
1005
1000
996
995
994
992
1006
1013
1014
1015
1017
1019
1022
Clarke's Projection.

Fig. 2.

An important question, which, as far as the writer is aware, has not yet been investigated, is whether the horizontal and vertical components of the wave vary in the same way throughout the year. Would experiments made with a horizontal aerial show the same variations in signal-strength from week to week as experiments made with a vertical aerial? According to Pickard[11] on the broadcasting frequencies (790 Kc.) at night the vertical component fluctuates much more than the horizontal component. Does this relation hold when diurnal, monthly, and annual changes are considered? The chief difficulty in attempting to answer this question by experimental evidence would be that at long distances the electric field is predominantly horizontal, the vertical component probably being too weak for investigation.

---

[11] G. W. Pickard, *Proc. I.R.E.*, April, 1926.

According to Prof. E. V. Appleton[6], when the waves are deviated below about 70 or 80 kilometres no abnormal polarisation is produced. If the waves are deviated above this height, both Kerr and Faraday effects will be produced. This will depend upon, among other things, the atmospheric pressure at different altitudes. If the pressure in the ionised regions changes, then the polarisation effects will change. This provides a probable connection between atmospheric pressure and signal-strength.

Changes in the polarisation due to changes in the earth's field are, in all probability, too small to be detected.

Prof. W. H. Eccles[12] suggests that diffraction effects due to the diminution of density of the atmosphere with height should be considered, and that the variations in signal-strength may be due to variations in, or movements of, the *lower* atmosphere. This is possibly another way in which atmospheric pressure can affect the signal-strength, though in this case the variations in the pressure at *lower* altitudes would have some effect. The diffraction effects on the shorter waves, however, may be too small to be appreciable. It should be noted that these effects, if appreciable, would not vary in the same way as the diffraction effects of Pickard, and Nichols and Schelling, one being due to changes in the atmospheric density at low altitudes, and the other being due to occasional space irregularities in the medium, *i.e.*, the temporary banking-up of ions.

In the considerations mentioned above, the variations in the atmospheric pressure appear to be the most important factor which may influence long-distance reception. This is the factor which the writer has investigated, and the results will now be described.

Variations in Atmospheric Pressure.

The writer obtained all the information concerning the pressure distribution across the North Atlantic from the weather charts kindly supplied by the Air Ministry Meteorological Office. As an example, the chart for 14th April, 1924, is reproduced in Fig. 2. On this date conditions for transatlantic reception were exceptionally favourable. Unfortunately, these charts are sometimes incomplete, no observations being received from North America. The pressure readings over the sea are supplied voluntarily by ships; when very few readings are received from ships the pressure distribution becomes doubtful, and in these cases the isobars are drawn as dotted lines. The full lines are the isobars when the pressure distribution is known with a greater degree of certainty. Also, there may be cases of an exceptionally deep depression, or a region of exceptionally high pressure, inside a particular isobar. For example, the pressure may rise to a very high value near the south coast of Greenland or in the " high " region just west of Florida. These remarks are intended to show that the charts are not absolutely accurate, and that it may be justifiable to alter the curves to a slight extent to suit the purpose in question. The weather charts are issued at about midday from the readings taken during the morning, but since the pressure distribution does not usually change a great deal in 24 hours, each chart may be taken to represent the state of the pressure during the previous night without incurring much error.

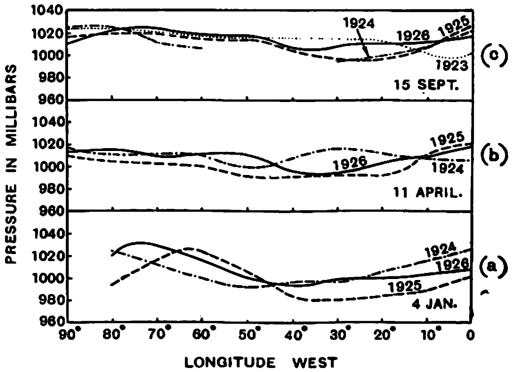


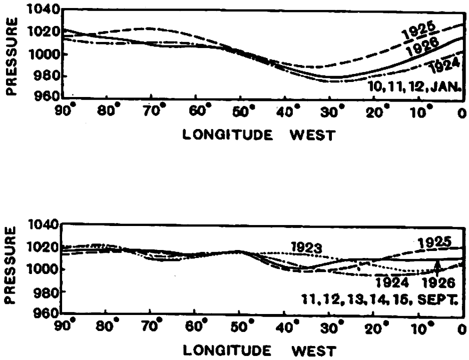
Fig. 3.

The method of drawing the pressure distribution curve from these charts will now be described. A curved line is drawn to join London to a point in the centre of the eastern side of the United States. This need not be any particular point, since the signals were received from practically the whole of the eastern half, and not from any particular station. It would, of course, be better to examine the isobars drawn on a great-circle map with London at the centre. A straight line drawn on this map would then represent the shortest distance between London and any other point. If the straight line between London and the eastern side of the U.S. on this map is transferred on to a map with the North Pole at the centre, as in the weather chart (Fig. 2), it becomes slightly curved, the North side being convex. Consequently, the line on the weather chart must be curved upwards to approach Iceland and Greenland. For each chart, the pressure as indicated by the isobars at points separated by 10 degrees of longitude along this curved line is noted. This is continued to 80 or 90 degrees west. These figures are then plotted on a separate chart against the longitude, and each curve thus obtained gives the pressure distribution along the line for one particular day.

---

[6] E. V. Appleton, *Nature*, 9th Oct., 1926.
[12] *Proc. Roy. Soc.*, 757A, May, 1926.

Now, if there is any connection between the pressure distribution across the Atlantic and transatlantic reception, it is reasonable to expect the pressure distribution curve for any particular day to be the same as for the same day in any other year, if the receiving conditions are the same on any given date for any year. That is, the pressure distribution curve for, say, 5th May, 1924, would have to be the same as the curve for 5th May, 1925, or any other year. To see whether this relation holds true, the writer drew the pressure distribution curves for parts of January, April, and September, of the years 1923-4-5-6. Unfortunately, many of the charts for 1923 were unobtainable; and it would seem to be impossible to attempt to trace any resemblance between the curves for periods before 1923, owing to the lack of material. Altogether, over 100 curves were drawn, and to reproduce them here would occupy too much space. An example, which represents the general appearance of the curves fairly well, is shown in Fig. 3 (a, b, c). Fig 3(a) shows how the pressure varied across the Atlantic on 4th January, 1924-5-6. It may be seen at the first glance that in each year, on this date, there was a depression over the Atlantic between longitudes 30 and 50 degrees west. The depression did not occur in exactly the same place each year, and similarly the pressure did not rise to a maximum at exactly the same place in the eastern part of the U.S. each year. This sort of discrepancy occurs in most of these curves. In many cases, however, a closer resemblance could be seen if the curve for, say, 5th May, 1924, was compared with the curve for 4th May, or perhaps 6th May, 1925. This seemed to show that the pressure distribution might be repeated annually, though perhaps a day too early or a day too late. In some cases it was two days too early or too late, but a discrepancy of this order can be permitted since the conditions for reception are at times as much as a whole week out. By drawing curves to represent the mean pressure distribution for three or four consecutive days of each year, such discrepancies would be eliminated. If the mean curves are drawn for, say, more than a week there is a tendency for the minor variations to disappear, in which case no comparisons could be effected. The writer drew the 3-day mean curves for January and the 5-day mean curves for September. (During September the pressure was much more stable, and the use of the mean curves for as many as five days was therefore considered justifiable.) As was expected, there was a much closer resemblance between these curves. Examples of these are shown in Figs. 4 and 5. It is remarkable to note how very closely the 5-day mean curves for 11-15th September (Fig. 5) agree, particularly over the U.S. between 50 and 90 degrees west. The observations over land are made at special meteorological stations, and those readings can be trusted to have a greater accuracy than the readings



Figs. 4 & 5.

taken voluntarily by ships. This may account for the discrepancies over the Atlantic (between 0 and 50° west). On the other hand, it may be that the pressure over water is naturally more variable than it is over land.

It is difficult to decide whether the resemblances are merely due to chance or whether they are due to any real repetition of pressure distribution. It may be argued that if there were any repetition of the pressure conditions, then there would necessarily be a similar repetition of the weather conditions. There is ample evidence to show that the weather conditions at any given point are not repeated annually in this way. It must be pointed out, however, that although the pressure *distribution* may be repeated annually with discrepancies (such as a 300-mile displacement of a depression), the *actual* pressure at any given point along the line may be quite different from year to year. It would, perhaps, be more accurate to say "distribution of weather" may be repeated every year. It can be seen directly from the weather charts as supplied by the Air Ministry that the high and low pressure regions occur in approximately the same place on corresponding dates in successive years, but obviously this method of representation is out of the question.

Connection between Pressure Distribution and *C*.

The actual connection between pressure distribution and the receiving conditions is a little obscure. The best way in which the general conclusions may be shown is by the diagrammatical representation of the relation in Fig. 6. It is seen that reception conditions may be either good or bad when the pressure is the same all the way across the Atlantic, depending on whether the pressure is high or low. A dip in the pressure when it is high seems to result in poor signals. A region of high pressure, provided it is confined to a small range, also results in poor signals. If the high-pressure region covers the greater part of the distance between the transmitter and receiver, then strong signals will be received. Fig. 7 shows the relation between the pressure distribution from England to South America and the signals received from Brazil. The same connection as for North America is seen to hold good here. Over a period of several weeks last winter the signals from North America were very poor, while signals from South America were good. At that time there was a deep depression, more or less stationary, between England and North America, whereas the pressure between England and South America was high. The writer has found that when the signals from South America are weak, there is always a depression in the path of the signals, and that the same relation applies to signals from North America.

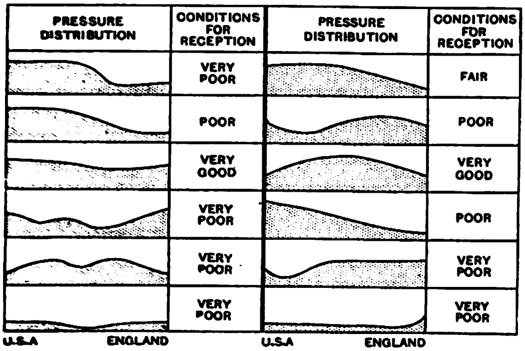


Fig. 6.—*General relations between pressure distribution and conditions for reception of signals from U.S.A. in England.*

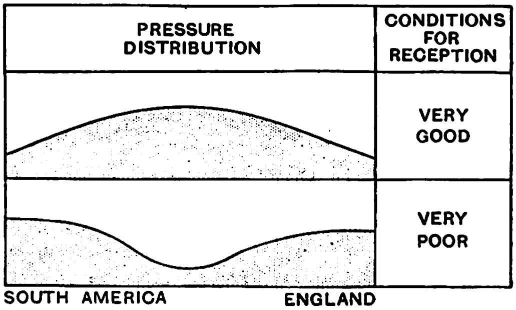


Fig. 7.—*General relations between pressure distribution and conditions for reception from Brazil.*

Observations on signals from New Zealand and Australia would, of course, be useless owing to the great distance and, therefore, the complexity of the effects. The distances traversed by European signals received in England are considered by the writer to be too short for the effect of the weather to be investigated satisfactorily.

The relation between pressure distribution and the received signals just described, and the probable effect of the atmospheric pressure on long-distance reception described under "Possible causes of the variations," led the writer to suggest the following theory.

In the first place, the assumption is made that, at altitudes of 50 kilometres or more, the atmospheric pressure varies in a manner similar to that in which it varies at sea-level. At present there seems to be no direct evidence for or against this, and the only experiments relating to this subject, as far as the writer is aware, are those referred to above, and they dealt with the pressures at altitudes of only 20 kilometres. It may seem probable that the pressure at an altitude of, say, 50 kilometres is practically constant throughout the year, and yet, on the other hand, when it is remembered that a depression may cover an area as much as 500 kilometres in diameter, it appears possible that owing to a depression at sea-level, the pressure at 50, or perhaps 100 kilometres above that area may similarly be reduced, though, of course, the percentage deviation from the mean pressure might be expected to decrease as the altitude increases. If the pressure changes in this way, it would, in all probability, follow the variations observed at sea-level,. On this assumption the pressure distribution curves would represent, though on a different scale, the pressure distribution across the Atlantic at high altitudes.

Now if the pressure changes at these altitudes, then the intensity of ionisation will also change. Thus if, during the day, the pressure at sea-level is decreasing, the pressure above that region will, it is assumed, also be decreasing, and consequently the absorption of the ultra-violet radiation from the sun will decrease, resulting in the formation of ions at a lower altitude. In other words, there would be an increasing dip in the ionised medium over the region where the pressure is decreasing. Conversely, if the pressure at sea-level is high, the ionised medium above this region will, in effect, be raised. It should be noted that if the pressure decreases during the night, there will not be any dip formed in the medium, since the source of ionisation is then removed, and no more ions will be formed at a lower altitude. The effect of a decrease in pressure would be to decrease the rate of recombination of the ions, *i.e.*, the rate of rise of the lower boundary of the medium. An increase in pressure during the night would result in an increased rate of rise of the lower boundary. These effects during the night would probably be noticeable only when the pressure is changing rapidly. The result would be, in any case, however, that the medium, or rather a layer of any given intensity in the medium, would follow the shape of the pressure distribution curve. This is the basis of the theory. It depends on an assumption which may, or may not, be justifiable.

Now, what will be the effect of the curvature of the "layer" on the path of a wave? Again, an idea of what is likely to happen according to this theory can best be conveyed by means of a diagram. In Fig 8(a) the pressure at the transmitter T and the receiver R is high, and between them there is a depression. On the assumptions pointed out above there will be a dip in the "layer" in the region of the depression. This, dip will be of the form shown in Fig. 8(a), and *not* of the form shown in Fig. 8(b), since the power of the ultra-violet radiation of producing an increased number of ions here will decrease as it travels downwards, due to absorption, and probably the lower boundary of the medium will remain unaffected. Consider a wave-front travelling upwards from T. As soon as it gets into the medium, the upper part of it will be accelerated, and the wave will be refracted over and returned to earth, but, due to the depression, the curvature of the "layer" is increased, so that the wave is deflected downwards before it has travelled to any great distance. Although only one path has been considered, it is clear that the effect is practically the same for various angles of propagation. Thus, a depression between the transmitter and the receiver will prevent waves from reaching the receiver, unless the depression is very close to the receiver. The dip is most marked at high altitudes, and since it is the very short waves which penetrate to the higher altitudes, the effect of the dip will be most marked on the very short waves. As the wavelength is increased, the height to which the wave penetrates will decrease, and the effect of the dip will also decrease. There is ample experimental evidence to show that the shorter the wave the

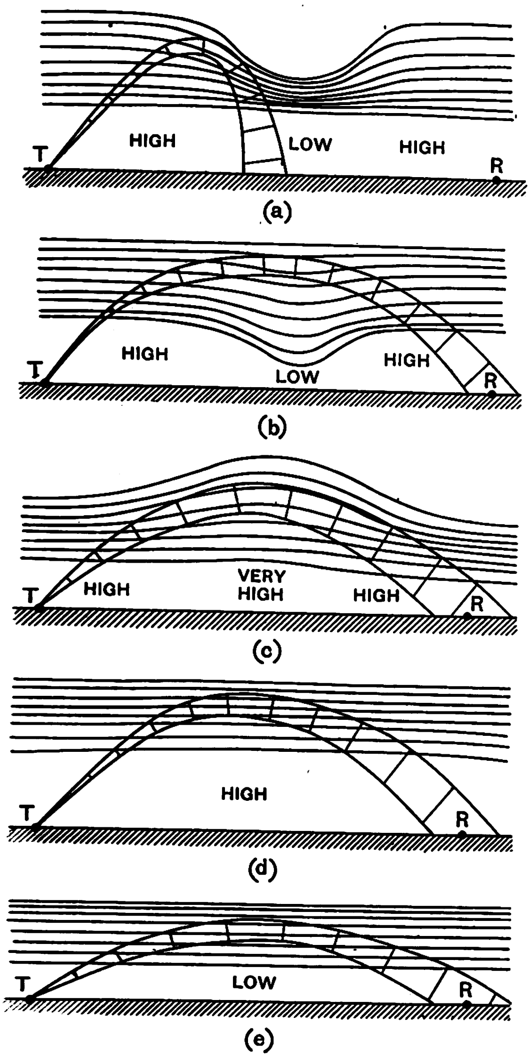


Fig. 8.—*Showing the path of a wave in the ionised medium. The lines in the medium represent layers of equal intensity of ionisation. The intensity increases upwards from the earth.*

more variable it is in its behaviour. This is in accordance with the theory. If, however, the wave is very long, say, several thousand metres, it will be reflected at low altitudes; but here the pressure varies more than at higher altitudes where the shorter waves are refracted. This will result in a large variation in the absorption of the wave-energy by the atmosphere, since the absorption depends upon the pressure. This agrees with L. W. Austin's experiments described in an earlier part of this article. It appears that for long waves it is the *pressure* variations which are important (being greater here than for short waves), and for short waves it is the *ionisation* variations which are important (being greater here than for long waves). If the pressure at *T* and *R* is low, and high between them, as in Fig. 8(c), the waves will be able to travel to greater distances: this corresponds to good conditions. Again, in Fig. 8 (d), where the pressure is high everywhere between *T* and *R*, conditions will be good, but if, as in Fig. 8 (e), the pressure is *low* everywhere, conditions will be poor, for this reason: due to the low pressure, the " layer " will have descended to a low altitude, and the wave will be forced to travel at low altitudes, but even here the pressure is low, and the result should be the same as in the case of a uniform pressure. Whenever there is a large area of low pressure, however, it seems to be generally accompanied by cyclones (which may not be recorded on the weather charts). Consequently, if the pressure appears to be uniformly low, there will almost certainly be a depression somewhere in the region, which corresponds to the case in Fig. 8(a). A comparison of Figs. 6, 7, and 8, shows that the conditions suggested by the theory are in accordance with experimental facts.

The writer submits this theory with some reserve, and in the hope that it will lead to a better understanding of the effect of the weather. He is convinced, however, that out of all the factors connected with the weather, which can affect long-distance reception, the atmospheric pressure is the most important. There is no hard and fast rule that can be made to apply to the changes either in pressure distribution or in long-distance reception: discrepancies occur in both of them, and these may be due to other effects such as temperature, or winds. However, evidence shows that the conditions for reception and the pressure distribution across the Atlantic are repeated annually in a complex but definite manner, and that there is a connection between them.

Information on transatlantic reception and atmospheric pressures for periods before 1923 is very difficult to obtain, and time only will show whether there is any real repetition as there appears to be at present, after three years of investigation.

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

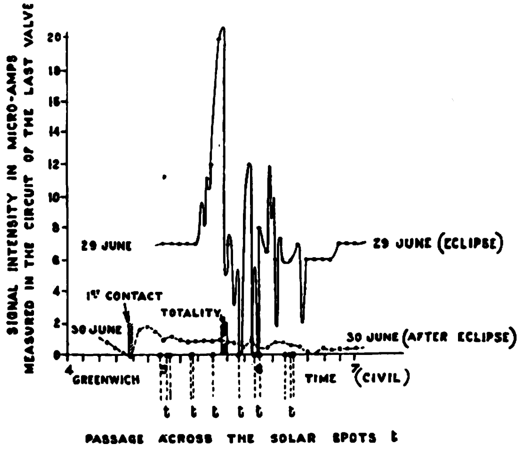
PROPAGATION OF WAVES.

COMPTE RENDU DES OBSERVATIONS FAITES PENDANT L'ECLIPSE DE SOLIEL DU 29 JUIN, 1927 (Report of the observations made during the sun's eclipse, 29th June, 1927).—H. S. Jelstrup. (*L'Onde Electrique*, 6, 69, pp. 445-460.)

The observations were made at Nordre Langen in East Norway, which was about in the middle of the zone of totality. The transmitting station observed was at Hamar, on the opposite side of the zone of the Heaviside layer suffering eclipse. A Marconi 7-valve receiver was employed, which is described in detail; the wavelength was 566 metres. The results are tabulated at length; a simultaneous series of astronomical and radio observations having been made. The following conclusions are drawn :—

1. The effects of the eclipse on the transmission of radio waves of medium length are similar to those ordinarily found at sunset : namely, increased intensity and increased fading; the intensity rising to its maximum a moment after the actual totality.

2. The intensity is strongly influenced when the moon passes over a spot situated near the sun's edge, as shown in the accompanying figure, with the occurrence of an extremely powerful and peculiar "atmospheric."



3. From the fact that the day and night before the eclipse audibility was mediocre while the evening afterwards it was excellent (and also some other considerations), the question is raised whether the moon approaching the sun has not some deviating action on the solar corpuscular radiation, emanating more particularly from the spots, and whether these variations, engendered by the moon in conjunction, may not manifest themselves by analogous variations in the ionisation of the Heaviside layer, and affect radio reception accordingly. In this way the author concludes, disturbed radio reception should be expected at the new moon.

DEVIATION OF WIRELESS WAVES AT A COASTAL BOUNDARY.—(*Nature*, 7th January, 1928, p. 35.)

A record of evidence in support of the suggestion that wireless waves are reflected at a coastline, mentioned by Dr. Smith-Rose in a letter to *Nature* of 9th September, 1925, p. 426.

Major Worlledge reports that during the calibration of a direction-finding station, last year, it was noted that the bearings on certain stations, using more than one wavelength, showed abnormal variations accompanied by sudden shifts of as much as 4 or 5 degrees on wavelengths in the neighbourhood of 1,000 metres: on systematic observation, it was found that the change in bearing was related in a harmonic manner to the frequency of the waves received, the period of this harmonic relation being consistent with the explanation that the change in bearings was due to the reflection of waves from the landward side of the neighbouring coastline. Directional error is a maximum when the wavelength is such that direct and reflected waves arrive in the same phase, while at intermediate wavelengths, blurred minima are observed as a result of the phase difference.

INFLUENCE DE LA NATURE DU SOL SUR L'EMISSION ET LA RECEPTION RADIOELECTRIQUES (Influence of the nature of the ground on wireless transmission and reception).—L. Bouthillon. (*L'Onde Electrique*, 6, pp. 533-553, November, 1927).

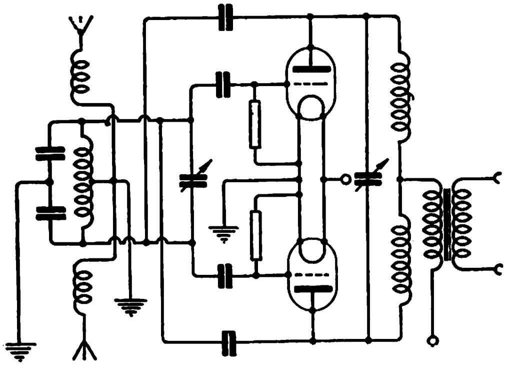
Paper presented at a meeting of the S.A.T.S.F., 8th February, 1927.

All ground behaves as a perfect conductor for waves sufficiently long (above 133 metres for sea water and 833 metres for damp earth), and as a perfect dielectric for waves sufficiently short (less than 33 metres for dry sand and 13 metres for fresh water), while cases in practice range between these two extremes. Recent experiments with short waves have complicated the problem, showing that the inclination of the waves and their polarisation have also to be taken into account. The complex problem is investigated for the four most simple systems: a vertical and a horizontal antenna and a vertical and a horizontal frame. The consequences of the investigation are pointed out: interpretation of certain results of experience (reception with horizontal antennæ or frames, polarisation of waves, small influence of the shape of the aerial in the case of short waves); the connection with Zenneck's theory; and lastly, the possibility of new methods of measuring the characteristics of electromagnetic fields.

Die Anwendung von kurzen Wellen im Verkehr mit Flugzeugen (The employment of short waves for communication with aircraft).—H. Plendl. (*Zeitschr. f. Techn. Physik*, 8, pp. 456-464).

Description of an investigation on the usefulness of short waves for aircraft communication (although certain writers have declared short waves of no value for this purpose on account of zones of silence and also the shaking of an aeroplane in flight and noise from the engine). Circuit-diagrams of the transmitting and receiving apparatus employed on the aeroplane in these experiments are shown in the figures.

The experiments showed that for distances greater than 1,000 km., short waves are probably a sure means of communication for aircraft, as good reception was obtained from foreign short-wave stations 1,500-20,000 km. distant; and that for distances less than 100 km., within which the so-called silent zones should occur, though there certainly was very considerable attenuation for some wave ranges, this nevertheless was never sufficient to entirely prevent communication.

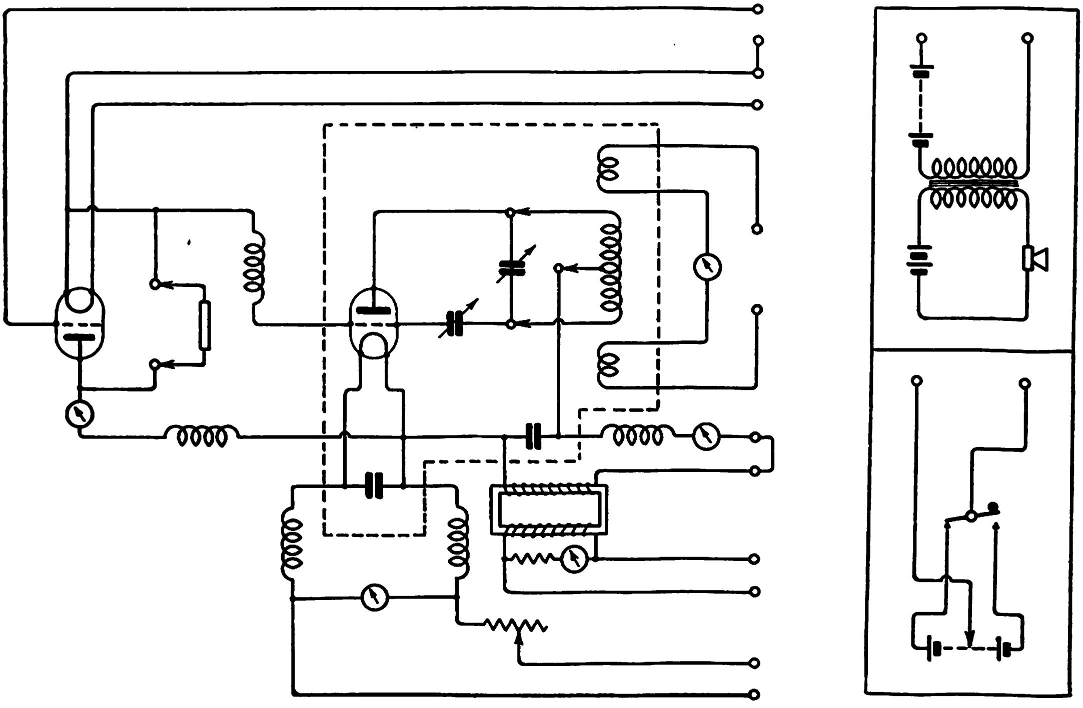

Circuit arrangement for reception on short waves.

The author concludes that nothing definite about the silent zones of a wave can be stated until a large number of repeated observations on that wave at different times have been made; further, the whole waveband of 10-150 metres must be investigated, and quantitative field-strength measurements carried out. He adds that research is also required on the optimum form of antenna, means of drive, and transmitter energy to employ.

Polarisation of Radio Waves.—J. Hollingworth and R. Naismith. (*Nature*, 4th February, 1928, p. 171.)

A letter describing interesting results recently obtained in connection with the propagation of long waves (14,350 metres).

In the course of simultaneous observations over a period from one hour before until one hour after sunrise of the same transmission from St. Assise by two stations, Slough and Aberdeen, roughly 400 and 1,000 km. from it and approximately on the same great circle, it has been found that in the period preceding sunrise the wave arriving at the nearest station is plane polarised, with its plane of polarisation rotated in a clockwise direc-


Transmitting circuit with separate keying or microphone arrangement.

tion when looking in the direction of propagation, whereas at the more distant station the rotation is anti-clockwise. By the time of sunrise both these abnormal polarisations have gradually decreased and disappeared, and in some cases at the nearer station the space wave appears to have entirely vanished also. About half an hour later, however, the space wave reappears at the nearer station, but this time with left-handed polarisation. This persists with varying intensity throughout the day, again disappearing about 15.00 G.M.T., when the right-handed polarisation returns for the night. It has also been shown that the wave reaching the far station has started from the transmitter at practically the same angle of elevation as the wave to the near station, and that its downcoming angle at the far station is comparatively steep.

From the evidence the authors believe it highly probable that we are here dealing with some form of doubly refracted ray of which one element is being received at each station. Further experiments on the subject are in progress.

ON THE ANOMALOUS DISPERSION AND ABSORPTION OF ELECTRIC WAVES.—S. Mizushima. (*Sci. Papers Inst. Phys. and Chem. Research, Tokyo,* 5, pp. 201–248.)

It is highly probable that the longer the wavelength of an electromagnetic oscillation, the greater will be the mass of the oscillator. Thus the spectroscopic phenomena of shorter waves are ascribed to the inter atomic oscillation and those of the longer waves to that of molecules or their conglomerates. Assuming the existence of a permanent dipole in a molecule; Debye proposed a theory for the anomalous dispersion and absorption of electric waves, which hitherto has not been confirmed by experiment. In the present investigation systematic measurement is made of the anomalous dispersion and absorption at various temperatures and wavelengths, and the results are discussed from the view-point of the dipole theory.

ATMOSPHERICS.

METHODS OF REDUCING THE EFFECT OF ATMOSPHERIC DISTURBANCES.—E. H. Armstrong. (*Proc. Inst. Radio Engineers,* 16, pp. 15–29; January, 1928.)

Description of a method of reducing the effects of atmospheric disturbances by selective means as distinguished from directional reception. The method is based on the establishment of a difference between the natural and the signalling waves by imparting to these latter a characteristic not found in the former. This difference is effected by producing at the transmitter two waves of closely adjacent frequency and radiating them alternately. Details of the working out of the method are given. Discussion on the paper is appended.

PROPERTIES OF CIRCUITS.

ZUR THEORIE DER ENDVERSTÄRKUNG (Theory of last stage amplification).—M. von Ardenne. (*Zeitschr. f. Hochfrequenz.,* 30, pp. 116–123, October, 1927.)

Formulæ are found for the least anode battery tension and the negative grid tension required, for distortionless reproduction, when inductive loud-speakers are working at their maximum output with high emission valves. It is shown what circumstances result when several loud-speakers are connected in series or parallel, or when several valves in parallel are used to drive the loud-speaker. Numerical and graphical solutions of the problem are shown by means of examples, also curves giving the dependence of the useful output of the loud-speaker on the internal resistance of the valve and the frequency.

DREI BEITRÄGE ÜBER SCHWINGUNGSERZENGUNG (Three contributions on the generation of oscillation).—G. Jobst. (*Telefunken-Zeitung,* 47, pp. 11–38, October, 1927.)

The first contribution deals with exceptional sources of emission in transmitting valves: considering secondary emission from the grid, its influence upon the operation of transmitting valves, the elimination of undesired and strengthening of desired effects; discussing also thermic emission from the grid due to rising of its temperature, leading to reversal of the grid current and reduction in efficiency; and just mentioning secondary emission from the anode which is of little practical importance.

In the second contribution determination is made of amplitude and frequency in oscillation generators with non-linear characteristics, a method being developed from a calculation of oscillation problems.

The third contribution considers dynatron oscillations of the first, second and third variety, and aperiodic changes in its condition, applying the method previously described, a modification being made for ambiguous functions.

APPARATE FÜR VERSTARKUNGS-MESSUNGEN AN MEHRFACHRÖHREN ODER ANDEREN IN KASKADE GESCHALTETEN RÖHREN-ANORDNUNGEN (Apparatus for amplification measurements on multiple valves or other valve-arrangements connected up in cascade).—F. Gabriel. (*Zeitschrift f. Hochfrequenz.,* 30, pp. 95–100 and 123–126, September and October, 1927.)

After explaining the necessity for measuring the amplification obtained from valves in cascade with alternating current, the author gives at length the theory of the measurements, and describes the apparatus, showing circuit connections and the method of constructing input and output instruments, with illustrations.

DER ABGESTIMMTE HOCHFREQUENZVERSTÄRKER (The detuned high-frequency amplifier).—W. Runge. (*Telefunken-Zeitung,* 47, pp. 50-63.)

Description of some fundamental calculations and methods of measurement that have originated in the Telefunken receiving laboratory when working out the detuned high-frequency amplifier.

GEKOPPLETE KREISE (Coupled circuits).—W. Kummerer. (*Telefunken-Zeitung,* 47, pp. 63-69, October, 1927.)

For the mathematical treatment of coupled circuit problems, one proceeds from the differential equation. By limiting oneself, however, to the stationary condition of a forced oscillation, it is simpler to make use of the symbolic method of calculation customary in heavy current technique, and to explain the action of coupled circuits on one another by the introduction of transferred resistance. The relations holding good generally are deduced and with their help the frequency of a self-excited intermediate circuit valve transmitter is found.

A VECTOR LOCI METHOD OF TREATING COUPLED CIRCUITS.—E. Mallett. (*Proc. Roy. Soc.*, A, 117, pp. 331-350, January, 1928.)

KEEPING H.F. OUT OF THE L.F. AMPLIFIER.—A. L. Sowerby. (*Wireless World*, 1st February, 1928, pp. 117-118.)

The theory of the series grid resistance.

RECTIFICATION AS A CRITERION OF DISTORTION IN AMPLIFIERS.—M. von Ardenne. (*E.W. & W.E.*, 5, pp. 52-55, February, 1928.)

TRANSMISSION.

ÜBER DIE ZIEHERSCHEINUNG BEIM LICHTBOGENGENERATOR (On oscillation hysteresis phenomena in the arc generator).—H. Poleck. (*Zeitschr. f. Hochfrequenz.*, 30, pp. 109-116, October, 1927.)

The author explains that when this paper was being printed, one on the same subject by Winkler appeared in the July *Zeitschrift* (these Abstracts, November, 1927, p. 695), but that while the starting point of both investigations is the same, they lead in different directions. Experiments are described in which oscillation hysteresis figures are obtained for both the fundamental wave and harmonics and compared with those of the valve transmitter. The detection of beats after a jump to the shorter coupling wave, between the longer wave, is mentioned, which has not been observed with valves, and there is a discussion of the influence of the arc capacity.

ÜBER DIE FELDER DER WECHSELSTROMLEITUNG MIT ERDE UND DER HORIZONTALANTENNE (On the fields of alternating current wires with earth and the horizontal antenna).—F. Pollaczek. (*Elekt. Nachr. Technik*, 4, pp. 515-525, December, 1927.)

Concluding part of a mathematical discussion begun in the July number of *E.N.T.*, pp. 295-304.

NEUERE ANWENDUNGEN DER MODULATIONSDROSSELN (Recent applications of modulating chokes).—L. Pungs and F. Gerth. (*Zeitschr. f. techn. Physik*, 11, pp. 471-473, November, 1927.)

THE DESIGN OF CHOKE COILS AND TRANSFORMERS WHICH CARRY A DIRECT CURRENT.—G. W. O. Howe. (*E.W. & W.E.*, 5, pp. 49-52, February, 1928.)

THE RADIATION RESISTANCE AND ENERGY CAPACITY OF HALF-WAVE AERIALS.—E. Green. (*E.W. & W.E.*, v, pp. 82-84, February, 1928.)

RECEPTION.

LOCATING AND CORRECTING PROPAGATED RADIO INTERFERENCE. — C. Evans. (*Electrical World*, 90, p. 1300.)

Description of an investigation to locate a source of radio interference found on the system of the San Antonio Public Service Company, which manifested itself as a low-frequency hum. It was discovered that one of the blades of a gang-operated disconnecting switch failed to make complete contact, resulting in a small arc between blade and jaw. It was this arc that had set up the oscillations of radio frequency, which were propagated throughout the city over the 13-kV. system. The basic frequency of the power current, 60 cycles, modulated the arc oscillations, resulting in the characteristic "60-cycle hum" that had complicated the investigation.

TRACING RADIO INTERFERENCE.—J. Hanly (*Electrical World*, 14th January, 1928, p. 101.)

Details are given of routine method of locating various kinds of trouble. Test set proves value of audio-radio selective arrangement.

AUTOMATIC VOLUME CONTROL FOR RADIO RECEIVING SETS.—H. A. Wheeler. (*Proc. Inst. Radio Engineers*, 16, pp. 30–39, January, 1928.)

A receiving set is described in which the radio frequency amplification is automatically controlled to give a nearly constant radio-frequency voltage at the detector, independent of differences in antenna signal voltage. This results in nearly uniform response at the loud-speaker from nearby and distant broadcasting stations and also reduces the effect of fading. The method employed consists in using the rectified carrier voltage to adjust the grid bias of the radio-frequency amplifier valves. Solutions of special problems that arise in carrying out this method are indicated.

A NEW METHOD OF USING RESISTANCE AMPLIFICATION WITH SCREENED GRID VALVES.—J. J. DOWLING. (*E.W. & W.E.*, 5, pp. 61–62, February, 1928.)

A NOVEL VALVE DETECTOR.—H. J. Neill. (*E.W. & W.E.*, 5, pp. 74–76, February, 1928.)

VALVE CURRENT FROM A.C. MAINS.—J. K. Jennings. (*E.W. & W.E.*, 5, pp. 77–82, February, 1928.)

QUALITY AND THE ANODE RECTIFIER.—A. L. Sowerby. (*Wireless World*, 25th January, 1928, pp. 87–90.)

LOW-FREQUENCY OSCILLATION.—U.I.G.P. (*Wireless World*, 4th January, 1928, p. 17.)

Some notes on recent investigations by the Ferranti research laboratories.

THE DANGERS OF DETUNING.—A.L.M.S. (*Wireless World*, 18th January, 1928, pp. 69–70.)

VALVES AND THERMIONICS.

ON THE EMISSION OF POSITIVE ELECTRICITY FROM HOT TUNGSTEN IN MULLARD RADIO VALVES. —P. Kumar Mitra. (*Philosophical Magazine*, 5, pp. 67–79, January, 1928.)

An account of the variation of positive emission with temperature and with applied potential difference, and of the growth and decay of positive emission current with time under various conditions. The results are tabulated and shown graphically.

ÜBER DEN EMISSIONSMECHANISMUS VON OXYDKATHODEN (On the mechanism of emission from oxide cathodes).—W. Espe. (*Wiss. Veröffentl. a.d. Siemens-Konzern V*, 3, pp. 29–45; Abstract in *Zeitschr. f. Hochfrequenz.*, 30, pp. 126–128, 1927.)

The paper is a systematic investigation of the mechanism of emission from cathodes containing barium, strontium and calcium oxides; there still existing some obscurity as to the process of emission from oxides as distinct from cathodes of pure metal.

DIE AUSTRITTSARBEIT VON ELEKTRONEN AUS ERDALKALIOXYDKATHODEN (The work of emission of electrons from cathodes with alkaline-earth oxides).—W. Espe. (*Wiss. Veröffentl. a.d. Siemens-Konzern V*, 3, pp. 46–61; Abstract in *Zeitschr. f. Hochfrequenz.*, 30, p. 128, 1927.)

INVESTIGATION OF THE THERMIONIC PROPERTIES OF THE RARE-EARTH ELEMENTS.—E. Schumacher and J. Harris. (*Journ. Am. Chem. Soc.*, 48, pp. 3108–14.)

MEASUREMENTS AND STANDARDS.

GERÄTE ZUR MESSUNG VON EMPFANGSFELDSTÄRKEN IN DER DRAHTLOSEN TELEGRAPHIE UND TELEPHONIE (Instruments for measuring field-strength in wireless telegraphy and telephony).—G. Anders. (*Zeitschr. f. techn. Physik*, 8, pp. 464–471, November, 1927.)

Apparatus for measuring large and small field-strength is described, and in particular an instrument constructed by A E G. Reliability tests are explained. The recording of field-strength is possible.

A NEW METHOD FOR THE CALIBRATION OF AMMETERS AT RADIO FREQUENCIES.—H. C. Hazel. (*Proc. Inst. Radio Engineers*, 16, pp. 70–74.)

Description of the construction and operation of a thermionic vacuum tube designed for the measurement of radio-frequency currents. The input circuit consists of a filament whose cross section is small enough for the "skin effect" to be negligible at the frequencies used. The filament is heated first by currents of known magnitude (at a low frequency) and again by radio-frequency currents to be measured. Electrons emitted by the heated filament are drawn to an anode sealed into the tube and a comparison of the resulting space currents indicates, if the necessary precautions are taken, the amount of current in the input circuit.

DIAGRAMME DES CHAMPS ELECTRIQUES MESURÉS À MEUDON PENDANT LE PREMIER SEMESTRE, 1927 (Graphs of the electric fields measured at Meudon during the first half of 1927).—(*L'Onde Electrique*, 6, pp. 603–605.)

The field-strengths measured at Meudon of Bordeaux, Nantes, Rocky Point, Rome and Leafield are shown graphically, for the first six months of 1927.

LE QUARTZ PIEZO-ÉLECTRIQUE COMME ETALON DE FRÉQUENCE (Piezo-electric quartz as frequency standard).—R. Jouaust. (*L'Onde Electrique*, 6, pp. 513–532 and 580–588, November and December, 1927.)

"Conférence de documentation" given before the S.A.T.S.F., 10th May, 1927.

Description and theory of the properties of quartz utilised in its employment as a standard of high-frequency, followed by some particulars of different methods of realising such a standard.

THE ACCURACY AND CALIBRATION PERMANENCE OF VARIABLE AIR CONDENSERS FOR PRECISION WAVEMETERS.—W. H. Griffiths. (*E.W. & W.E.*, 5, pp. 17–24 and 63–74, January and February, 1928.)

SUBSIDIARY APPARATUS AND MATERIALS.

THE VACUUM TUBE RECTIFIER: OSCILLOGRAPHIC AND VACUUM TUBE VOLTMETER (Study of its Application to B-Voltage Supply for Radio Receivers).—J. Kuhlmann and J. Barton. (*Jour. Amer. Inst. E.E.*, 47, pp. 17-24, January, 1928.)

The paper covers investigations made in undertaking the design of a rectifier for use as the B power supply for radio receivers. It determines the most satisfactory type of filter circuit and the appropriate values of inductance and capacitance to give a D.C. output delivered with the least practical voltage drop and having no fluctuations of sufficient magnitude to interfere with the proper operation of the set. A vacuum-tube peak voltmeter used to detect very small fluctuations is described.

ÜBER DIE NICHTLINEARE VERZERRUNG VON LAUTSPRECHERN UND FERNHÖRERN (On the non-linear distortion of loud-speakers and telephones).—E. Meyer. (*Elekt. Nachr. Technik*, 4, pp. 509-515, December, 1927.)

DIE ANWENDUNG DER QUECKSILBERDAMPFRÖHRE ALS SCHALTORGAN (The employment of the mercury vapour tube as a switch).—H. Schuchmann. (*Zeitschr. f. techn. Physik*, 8, pp. 489-491, November, 1927.)

FURTHER NOTES ON THE REFLEX VOLTMETER.—W. B. Medlam and U. A. Oschwald. (*E.W. & W.E.*, 5, pp. 56-60, February, 1928.)

PAXOLIN.—W.I.G.P. (*Wireless World*, 11th January, 1928, pp. 29-32.)

A survey of the properties of this support for inductances carrying H.F. currents, and its manufacture.

STATIONS: DESIGN AND OPERATION.

Radio in Sweden.—(*Electrician*, 20th January, 1928, p. 76.)

Swedish broadcasting in 1927 yielded a net profit of about 600,000 kronor, as against 400,000 the previous year. According to the statistics published by the Royal Telegraph Department, the number of radio licences per thousand inhabitants in European countries is now highest in Sweden, with 53.6, next comes England with 53, and then Denmark, 44.8; Austria, 43; Germany, 28.1; Norway, 22.1; Switzerland, 15.9; Czechoslovakia, 15.2; Hungary, 9; Finland, 8.8; and Belgium, 4.6. At the Geneva Conference, Sweden was allotted five exclusive short wavelengths, varying between 200 and 600 metres, now used by six different broadcasting stations in Sweden. The increased demand for new stations has led to experiments in running two or several broadcasting stations on the same wavelength, but this problem has not been fully solved, and therefore at present it has been decided to raise the power of the Gothenburg and Malmo stations from 0.5 kW to 10 kW, and so increase their range.

RADIO IN FRANCE.—(*Electrician*, 13th January, 1928, p. 49.)

Broadcasting in France is in process of reorganisation. Three national and eighteen regional broadcasting stations are to be created. The first regional station will be constituted by the present station at the Postal Telegraph and Telephone School, known as the P.T.T., with its power increased and the programmes improved. The other two will be established by the resources of the "Syndicates of Users," and it is expected that the eighteen district stations will be constructed in two or three years. In order to meet the expense which will fall upon the State by this reorganisation, the licence fee will be increased from one to ten francs.

EGYPT: RADIO TELEGRAPHY.—(*Electrical Review*, 20th January, 1928, p. 108.)

Further extensions of Marconi wireless telegraph services are announced. A high-speed duplex service was inaugurated directly between London and Constantinople on 1st January, and from 15th January the Egyptian service hitherto operated by the British Post Office will be operated by the Marconi Company in London and by the Marconi Radio Telegraph Company of Egypt in Cairo. The Abu Zabal station has been acquired by the latter company and in future will be used only as a transmitting station, while a new receiving station has been constructed at Meadi, a few miles to the south of Cairo, in order to provide a high-speed duplex service in place of the present simplex service. Both transmitting and receiving stations are connected by special landlines to a new central telegraph office in Cairo, where all operating processes will be carried out.

UNITED STATES: RADIO TELEGRAPHY.—(*Electrical Review*, 3rd February, 1928, p. 197.)

The lease of the high-power transoceanic radio station at Sayville, Long Island, by the Postal Telegraph Company, the Commercial Cable Company, and the newly-formed Mackay Radio Company is an important step in ship-to-shore communication to compete with the existing organisations. The Sayville station was originally operated by the German Telefunken Company, who built it in 1912, its chief purpose being to communicate with Nauen. It was taken over by the U.S. Navy radio service in July, 1915. World-wide communication such as is planned will mean combination of cable and radio services, each supplementing, but not necessarily supplanting, the other.

WIRELESS EQUIPMENT OF THE MOTOR SHIP "BERMUDA."—(*Electrician*, 30th December, 1927, p. 828.)

Brief account of the Marconi equipment on the new liner, involving a departure from standard ship installation.

A SUPER-RECEIVING STATION.—A. Dinsdale. (*Wireless World*, 18th January, 1928, pp. 68-69.)

Some details of the new transoceanic relay station at Belfast, Maine, U.S.A.

GENERAL PHYSICAL ARTICLES.

NEW RESULTS ON COSMIC RAYS.—R. A. Millikan and G. H. Cameron. (*Supp. to Nature*, 7th January, 1928, pp. 19–26.)

Substance of the discourse, with additions, delivered by Prof. Millikan on 2nd September, at Leeds, during the B.A. meeting.

Cosmic rays are defined as that small portion of the "penetrating radiation" which is of cosmic origin. The main purpose of this paper is to present a preliminary report of very recent work on these rays, which throws new light on their properties.

The writers trace each step in the work on cosmic rays from the time when the presence of very penetrating radiation was first detected by Rutherford and McLennan in 1903, owing to its getting through the thick screens of their electroscopes; down to Millikan's latest results, revealing the existence of cosmic rays so hard that they are able to penetrate about 5 metres of lead before being completely absorbed.

For the most penetrating of the cosmic rays, the experiments indicate a wavelength of only 0.00021A, which is far shorter than the shortest of the γ-radiations from any known radio-active material and corresponds to a generating potential of nearly 60,000,000 volts. Magnitudes of this order require change taking place within the nucleus itself, since no extra nuclear changes are associated with anything like such energy. Although the fact that cosmic rays are non-directional means that they must come chiefly from beyond the Milky Way, either from the spiral nebulæ or from the very attenuated matter that pervades all space, the numerical value of the energy at present found for the rays is not such as to justify their being regarded, as yet, as providing direct experimental evidence of the transformation of matter into radiation in outer space. The total energy flowing into the top of the earth's atmosphere in the form of the cosmic rays is computed to be 3.1×10^4 ergs. per sq. cm. per sec., or just one-tenth the total energy coming into the earth's atmosphere in the form of starlight and heat.

THE TEMPERATURE COEFFICIENT OF OSCILLATING QUARTZ PLATES.—R. Strout. (*Physical Review*, 31, p. 156, January, 1928.)

Abstract of a paper presented at the Chicago meeting of the American Physical Society, November, 1927.

The change of frequency with temperature of a quartz crystal plate, $1.8 \times 1.8 \times 0.11$ cms., vibrating in a direction normal to its faces with a frequency of 2,700 kc., was determined at various temperatures. A second oscillating plate was used as a fixed frequency, while the heterodyne note was heard with a receiving set. This second plate was maintained at or near room temperature, and was reground to an appropriate frequency for each determination. The change of frequency with temperature was found to decrease linearly from 61.3 cycles per degree at 65° C. to 4.3 cycles per degree at $-189°$ C.

PREFERRED ORIENTATION IN TUNGSTEN CRYSTALS CAUSED BY MECHANICAL WORKING.—H. De Vore and W. Darcy. (*Physical Review*, 31, p. 160, January, 1928.)

Abstract of a paper presented at the Chicago meeting of the American Physical Society, November, 1927.

VEKTORDIAGRAMME BEI STROMRESONANZ (Vector diagrams in the case of current resonance).—E. Roessler. (*Elekt. Nachr. Technik*, 4, pp. 525–533, December, 1927.)

When all losses are taken into account, this case appears very complicated. For practical purposes, however, the relations can be very considerably simplified, the vector diagram of the apparent resistance as a function of the frequency becoming a circle, and the current diagram a straight line.

GENERAL CONSIDERATIONS ON THE PHOTO-ELECTRIC EFFECT.—P. W. Bridgman. (*Physical Review*, 31, pp. 90–100, January, 1928.)

It is suggested that the considerations of this paper enable another significance to be attached to the argument of Lawrence that photo-electric and thermionic emission are identical.

ON A PHOTO-ELECTRIC THEORY OF SPARKING POTENTIALS.—J. Taylor. (*Proc. Roy. Soc.*, A, 117, pp. 508–516.)

A paper describing a photo-electric theory of sparking potential, according to which the latter is a function of the photo-electric emissivity of the cathode for the radiations accompanying the neutralisation of the positive ions at the cathode surface. It is assumed that no ionisation by collision is produced by the positive ions in the gas.

RESONANCE RADIATION IN EXCITED NEON.—Y. Fujioka. (*Sci. Papers Inst. Phys. and Chem. Research*, Tokyo, 7, pp. 27–34.)

ELECTRODELESS DISCHARGES.—J. S. Townsend. (*Philosophical Magazine*, 5, pp. 178–191, January, 1928.)

A REPLY TO THE PAPER, "IONISATION BY COLLISION."—J. Taylor. (*Philosophical Magazine*, 5, pp. 445–446, February, 1928.)

THE BOLTZMANN-HOPKINSON PRINCIPLE OF SUPERPOSITION AS APPLIED TO DIELECTRICS.—F. D. Murnaghan. (*Journ. Amer. Inst. E.E.*, 47, pp. 41–43.)

A paper showing that the principle of superposition, shown for some time in experiment, is a necessary consequence of Maxwell's theory, and further, that the principle is valid for any theory leading to a system of linear differential equations with constant coefficients.

EINE NEUE METHODE DER KLANGANALYSE (A new method of sound analysis).—M. Grützmacher. (*Elekt. Nachr. Technik*, 4, pp. 533–545. *Zeitschr. f. techn. Physik*, 11, pp. 506–509 (abridged).)

EIN REGISTRIEVENDER SCHALLMESSER UND SEINE ANWENDUNGEN (A recording sound-meter and its applications).—E. Gerlach. (*Zeitschr. f. techn. Physik*, 8, pp. 515–519.)

Description of an electro-acoustic measuring arrangement with photographic recording, which can be employed for the measurement of loud-speakers, microphones, amplifiers, filter-chains, gramophone writers, etc. It can also be used to investigate sound absorption and reflection as well as for harmonic analysis.

THE RESULTS OF CLASSICAL WAVE MECHANICS OBTAINED BY USING THE METHODS OF RELATIVITY MECHANICS.—T. Lewis. (*Philosophical Magazine*, 5, pp. 408–416, February, 1928.)

MISCELLANEOUS.

RÉCEPTIONS RADIOTÉLÉPHONIQUES SUR TRAINS EN MARCHE (The reception of radio telephony on moving trains).—R. Saglio. (*L'Onde Electrique*, 6, pp. 589–602.)

An account of tests made by the Orleans Railway Company as to the possibility of the reception of broadcasting by passengers during long journeys. While it is found that the reception of waves emitted by a distant antenna leaves much to be desired, this apparently is no longer the case when the waves are guided by a carrier wire close to the line. A note is added by M. Lange in which he testifies to the good quality of the reception he found last year on the Berlin-Hamburg line, where a combination of guided wave and radio is employed, an antenna being erected on the roof of the train to pick up the communication from the wire alongside the line.

Signalübertragung auf fahrende Züge mittels Wechselstrominduktion und Resonanz (Signal communication on moving trains by means of alternating current induction and resonance).—P. Tätz. (*Telefunken-Zeitung*, 47, pp. 70–78, October, 1927.)

United States: Television.—(*Electrical Review*, 20th January, 1928, p. 109.)

The first demonstration of broadcast radio television arranged by the Radio Corporation of America is reported to have been successfully carried out on 13th January before groups of engineers, scientists and newspaper men, who, standing before home television sets, saw moving images and heard voices of a man and woman transmitted from the General Electric Co.'s laboratories several miles distant. The receiving sets were installed in three different homes, and all functioned equally well. Transmission was on a 37.8 metre wavelength, while the voice was simultaneously conveyed on 379.5 metres.

D.E.H.

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPRECOJ DE CIRKVITOJ.

La Desegnado de Ŝokbobenoj kaj Transformatoroj, kiuj Portas Kontinuan Kurenton.

Redakcia artikolo pritraktanta la modifon de induktanco, kiu okazas kiam Kontinua Kurento ĉeestas en ferkerna bobeno. La ciklo de magnetigo kaj la histereza kurvo estas unue konsiderita, sekvita de la kampo de magnetigo, kaŭze de malgranda Alterna Kurento surmetita sur ekzistantan Kontinuan Kurenton. La efekto de aera interspaco en la magneta cirkvito estas tiam pritraktita, kaj oni montras, ke ĉi tio eble havos la efekton igi, ke la malgranda kurvo de A.K. magnetigo estu pli krute klinita, tiel ke, la efektiva A.K. induktanco estas pligrandigita. La aera interspaco por optimumaj kondiĉoj estas pliposte diskutita laŭ la laborado de T. Spooner kaj C. R. Hanna (Usono). Esprimoj estas donitaj por la fluo en diversaj okazoj, kaj kurvoj estas montritaj por faciligi desegnadon, kun rimarkigoj pri praktikaj metodoj de desegnado rilate al aera interspaco, nombro da turnoj, k.t.p.

RICEVADO.

Valva Kurento pere de Alternkurentaj Ĉeftuboj.—J. K. Jennings.

La artikolo priskribas metodon uzitan de l'aŭtoro por havigi filamentan kaj anodan provizojn pere de A.K. ĉeftuboj. La senfadena aparato havas konvenciajn konektaĵojn. Transformatoro kun kvar vindaĵoj konsistas el la bobenoj :—(1) Primario por konekto al la A.K. ĉeftuboj, (2) por filamenta provizo al la aparato, (3) por filamenta provizo al la rektifikatoro, (4) por A.T. provizo al la rektifikatoro. Sekvas priskribo pri l'aparato de l'aŭtoro, inkluzive la dimensioj de la fero, la diversaj vindaĵoj, k.t.p. Notoj estas ankaŭ donitaj pri la ĝeneralaj aranĝoj kaj kunmetado.

Rektifado kiel Kriterio pri Distordado ĉe Amplifikatoroj.—M. von Ardenne.

Ĉi tiu artikolo pritraktas la fakton, ke miliampermetro povas esti uzita en la anoda cirkvito de amplifa valvo por indiki distordadon, kies ĉeesto estas evidentigita per iu ajn movo de l'instrumento, kaŭze de rektifado je foriro for de rekta parto de l'anoda kurvo. La efekto de transpaso al kurba parto de l'kurvo estas konsiderita, kun esprimoj por la permesebla krada migro, kaj la diferenco de kurveco inter la statika kaj dinamika karakterizoj estas ilustrita kaj diskutita. La " distorda faktoro " estas derivita, kaj oni deduktis, ke miliampermetro en la anoda cirkvito de potenca valvo devus ne varii pli ol 0.05 de sia konstanta cifermontrado por obteni bonan ricevadon per laŭtparolilo.

Noveca Valva Detektoro.—H. J. Neill.

La detektoro priskribita estas laŭ la formo de ekvilibrita de-modulatoro, funkcianta laŭ la konversa maniero de l'ekvilibrita modulatoro de transatlantika sendada praktiko. La kradoj de du valvoj estas konektitaj al kontraŭaj finaĵoj de fermita oscila cirkvito, kun krada potencialo aplikita pere de centra konektaĵo, dum la anodoj estas provizitaj per komuna rezistanco kun kupla kondensatoro el la kuniĝo de rezistanco kaj anodo. La karakterizoj de ambaŭ valvoj devus esti preskaŭ identaj, kaj la aŭtoro donas notojn pri diversaj tipoj de valvoj provitaj. Oni diras, ke konsiderinde malpliigita valoro de altatensia voltkvanto povas esti uzita.

Nova Metodo por Utiligi Rezistecan Amplifadon per Skrenitaj Valvoj.—J. J. Dowling.

La aŭtoro unue konsideras la ekzemplon de rezisteca kapacita kuplado per triodo, ilustrante la rezonadon per familio de anodvoltaj/anodkurentaj kurvoj. La rezonado estas etendita al skrenita valvo, kun interrespondaj kurvoj. Li poste montras, ke se la laboro estas limigita al la regiono de la anodvolta/anodkurenta kurvo, kiu klinas malsupren (super regiono de ĉirkaŭ 30 anodaj voltoj) tre granda amplifado estas obtenebla super etega enmeta amplekso (proksimume po centonoj da volto). Eksperimenta kontrolado de ĉi tiu rezulto estas priskribita, pligrandigo de 150–oblo estante citita.

SENDADO.

La Radiada Rezisteco kaj Energia Kapacito de Duonondaj Antenoj.—E. Green.

La aŭtoro unue aludas al opinio, ke estas malfacile havigi percepeblan potencon en anteno per mallongaj ondoj, pro ĝia malgranda kapacito. Ĉi tio, li diras, estas malprava, kaj estas efektive la kontraŭo de la vero.

Li poste deduktas tipajn ciferojn por duonondlonga anteno uzita por mallongaj ondoj, kaj kompilas tabulan komparon inter tia anteno kaj la Rugby'a anteno, laŭ la ciferoj de S-ro. E. H. Shaughnessy (vidu *E.W. & W.E.*, Majo, 1926a). Ĉi tiu komparo montras 80% da efikeco por la duononda anteno, komparite je 26.5% por la Rugby'a anteno.

Mallonga matematika diskutado estas poste donita pri la radiada rezisteco kaj pri la proporcio de maksimuma tensio kontraŭ maksimuma kurento por la duonondlonga anteno.

HELPA APARATO.

Pluaj Notoj pri la Refleksa Voltmetro.—W. B. Medlam & U. A. Oschwald.

La aŭtoroj larĝe pritraktas la priskribon pri la "Refleksa" tipo de termiona voltmetro (priskribita de ili en *E.W. & W.E.*, Novembro, 1926a), en kiu rezistanco inter la altatensia kaj malaltatensia baterioj estas komuna ĉe krada kaj anoda cirkvitoj, tiel ke la potenca diferenco naskita trans ĝi, kaŭze de anoda kurento, agas kiel krada potencialo. La efekto de kondensatoro trans ĉi tiu rezistanco estas poste diskutita, kaj oni diras, ke estas preferinde normigi kaj utiligi la voltmetron kune kun tia kondensatoro. Poste pritraktitaj estas valoroj de rezisteco kaj de altatensia voltkvanto, la efekto de ilia variado estante montrita, per serio de normigaj kurvoj.

La aŭtoroj tiam diskutas la forekvilibrigon de komenca kurento per mekanikaj rimedoj kaj elektraj rimedoj, kaj priskribas la aranĝon de du-skala voltmetro, kun specimenaj skaloj kaj notoj pri funkciigo.

Laste priskribita estas refleksa tipo de voltmetro kun seria krada kondensatoro, permesanta ĝian uzon en la ĉeesto de kontinua kurento.

La Korekteco kaj Normigada Daŭreco de Varieblaj Aerkondensatoroj por Precizecaj Ondometroj.—W. H. F. Griffiths.

Findaŭrigita el antaŭa numero, priskribinta novan formon de precizeca aerkondensatoro, ĉe kiu la apudaj dielektrikaj interspacoj estas elektre en serio, kaj estas ankaŭ komplementaj. En ĉi tiu parto la aŭtoro unue konsideras la amplekson de l'eraroj enkondukitaj de la kapacito inter apudaj movaj platoj, ilustrante amplekse la efekton je diversaj gradoj de rotaciado. Detaloj estas donitaj pri la skrenaj aranĝoj, por korekti ĉi tion, enkorpigitaj en la fina desegno; ankaŭ pri la kompletaj skrenaranĝoj de la tuta kondensatoro. La proporcio de maksimuma/minimuma kapacito estas poste diskutita, kun esprimoj por la kompleta kapacito de la kondensatoro. Notoj pri aliaj detaloj de desegnado estas ankaŭ donitaj, kaj la aŭtoro finas per priskribo pri l'utiligo de la kondensatoro ĉe malalta dekrementa ondmetra cirkvito, traktante ankaŭ pri tre sentema metodo de resonanca detektado. Nerigide kuplita kristala cirkvito estas uzita, kune kun du galvanometroj, unu kiel proksimuma indikatoro por serĉi, kaj la alia kiel sentema indikatoro permesanta tre precizan alĝustigon, la pliboniĝo de precizeco estante ilustrita.

DIREKTA SENFADENO.

Rotaciantaj-kadraj Radio-sendiloj.

Oni presigas resumojn de tri prelegoj pri la ĉi-supra temo, legitaj ĉe la Senfadena Sekcio de la Institucio de Elektraj Inĝenieroj, Londono, je 4a Januaro, 1928a.

(1) Rotaciantaj-Kadraj Radio-Sendiloj kaj ilia aplikado al Direkto-Trovado kaj Navigado.—de T. H. Gill kaj N. F. G. Hecht, M.I.E.E.

(2) Kelkaj Eksperimentoj pri l'Aplikado de la Rotacianta-Krada Sendilo al Mara Navigado.—de R. L. Smith-Rose, D.Sc., Ph.D., A.M.I.E.E., kaj S. R. Chapman, M.Sc., A.M.I.E.E.

(3) Teoria Diskutado pri Diversaj Eblaj Antenaranĝoj por Rotacianta-Kadraj Sendiloj.—de R. L. Smith-Rose, D.Sc., Ph.D., A.M.I.E.E.

DIVERSAĴOJ

Resumoj kaj Aludoj.

Kompilita de la Radio-Esplorada Komitato (*Radio Research Board*), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

La Ekspozicio de la Fizika Societo.

Rakonto pri aferoj de senfadena kaj laboreja intereso ĉe la Dekoka Ĉiujara Ekspozicio de la Fizika Societo kaj la Optika Societo, tenita ĉe la Imperia Kolegio de Scienco kaj Teknologio, South Kensington, Londono, je la 10a, 11a, kaj 12a de Januaro, 1928a.

La revuo diskutas la aparaton montritan sub la rubrikoj "Elektraj Mezuraj Instrumentoj," "Laboreja Ekipaĵaro," "Senfadenaj Akcesoraĵoj, Partoj kaj Aparatoj," "Esplora kaj Eksperimenta Sekcio," kaj estas ilustrita per fotografaĵoj, unu, kun aparta intereso, estante pri la nova tipo de precizeca kondensatoro priskribita en *E.W. & W.E.*, de Januaro kaj Februaro, 1928a.

Libro-Recenzo.

Recenzo de D-ro. R. L. Smith-Rose estas donita pri la verko "*Wireless Directional Finding and Directional Reception*" (Senfadena Direkto-Trovado kaj Direkta Ricevado), de R. Keen, B.Eng., A.M.I.E.E., dua kaj pligrandigita eldono, eldonita de la posedantoj de *E.W. & W.E.*

Some Recent Patents.

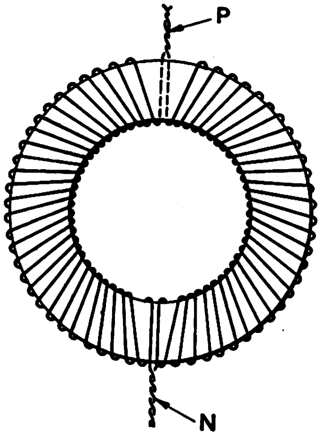
The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

THE TORUSOLENOID.

(*Convention date* (*U.S.A.*), *15th March*, 1926. *No.* 267474.)

The form of winding shown in the Figure has been christened the Torusolenoid in America, presumably because it combines the "closed-field" advantage of the ordinary Toroid with the special feature that the input and output terminals are spaced widely apart as in a solenoid coil.

The wire is laid around a magnetic core in two symmetrical halves which are wound in opposite senses, so that the output terminal *N* lies diametrically opposite the input *P*. When a current passes through the two windings in parallel, the adjacent ends develop magnetic poles of opposite sign so that a closed magnetic field exists inside the core.



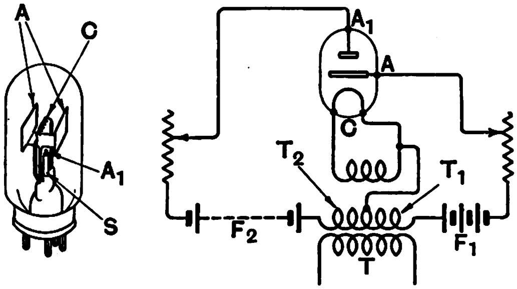
Owing to the wide separation of the terminals' capacity coupling such as is liable to arise in the ordinary Toroid, when used for very high frequencies, is avoided. In addition the standard Toroid with closely adjacent terminals forms, in effect, a single-turn winding which sets up a corresponding small external field. In the Torusolenoid the two windings form two single half-turns, each carrying current in the same direction, so that the external field is completely neutralised.

Patent issued to The Dubilier Condenser Co.

A DUAL-SUPPLY RECTIFIER.

(*Convention date* (*Germany*), *31st March*, 1926. *No.* 268764.)

The rectifier tube shown in Fig. (a) is designed to supply a comparatively heavy charging-current at a low voltage, simultaneously with a relatively small charging-current at a high voltage, so that the same installation can be used for recharging both a filament accumulator and a wet-cell type of H.T. battery. The glowing cathode *C* co-operates with two anodes *A* and A_1. The anode *A* is of large surface and practically surrounds the cathode, so that it absorbs the bulk of the electron discharge stream. The second anode A_1 is a mere point of wire which protrudes from an insulating sleeve *S* of quartz.



(a) (b)

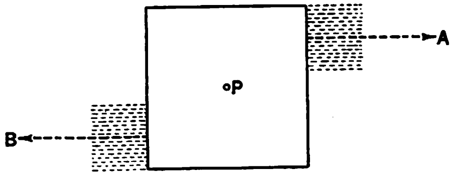
The circuit arrangement is shown in Fig. (b). The main secondary winding of the supply transformer *T* is in two parts, one T_1 consisting of a few turns of relatively thick wire, whilst the other T_2 comprises a larger number of turns of thinner gauge. A large amperage at low voltage is drawn from the main anode *A* to charge the filament accumulator F_1, whilst a smaller current at higher pressure is supplied from the point anode A_2 to the H.T. battery F_2.

Patent issued to Accumulatoren-Fabrik.

MECHANICAL PIEZO EFFECTS.

(*Convention date* (*Germany*), *8th April*, 1926. *No.* 276037.)

When a piezo crystal is set into vibration by the application of an alternating E.M.F., it is known that the resulting molecular deformations react upon the air in the immediate vicinity of the crystal, and set up a train of compression waves.



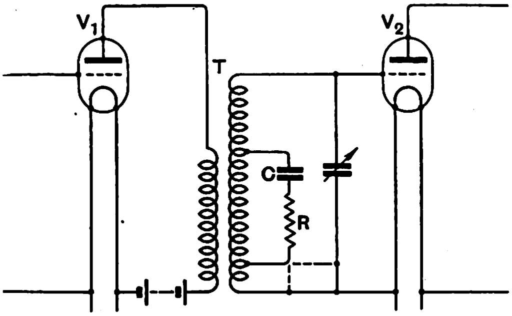
By cutting the crystal asymmetrically, the inventor arranges that these air currents are located at definite points such as *A* and *B* so that they produce a torque tending to rotate the crystal bodily about a pivot *P*. The effect is used to indicate and measure the intensity of electric oscillations.

Patent issued to the Telefunken Co.

STABILISING CIRCUITS.

(*Application date, 6th July*, 1926. *No.* 281740.)

One drawback of certain known methods of preventing inter-electrode capacity coupling is that when the adjustments are such as to prevent self-oscillation on the higher frequencies, regeneration on the lower frequencies is *ipso facto* reduced to a point lower than is really necessary, so that the overall amplification is not constant. Another defect is a loss in the true quality of distant reception owing to excessive selectivity and consequent "trimming" of the side bands.



The Figure shows a circuit arrangement for ensuring stability without introducing either of these drawbacks. The coupling transformer *T* is so arranged that part of the primary winding is more closely coupled to one portion of the secondary than to the remainder of the same. To avoid excessive regenerative effects, a load is associated with certain of the secondary windings and is of such a nature that the voltage induced into the secondary is maintained constantly out of phase with the inducing currents; or conversely the induced current is kept in phase-opposition with the inducing voltage.

The load consists of a condenser *C* inserted in series with a resistance *R* across a number of turns on the secondary. The value of the load, and the number of secondary turns shunted, depend upon the impedance of the valves V_1, V_2, and upon other circuit constants. Definite values are given in the specification, together with a vectorial analysis of the various voltage which may exist, at any one instant, in a typical amplifying circuit.

Patent issued to the Gramophone Co., Ltd.

AERIAL SYSTEMS.

(*Application date, 8th September*, 1926. *No.* 281762.)

An antenna is energised from the power house by a single-wire feeder of any length, the effective resistance of the antenna being made equal to the surge impedance of the wire by the insertion of suitable loading resistances at distances corresponding to odd quarter-valve lengths along the wire, together with inductive or capacitative impedances to neutralise the inherent inductance or capacity of the wire at the working frequency. Under these conditions energy flows along the wire from the generator to the loaded point, and is then completely absorbed by the resistance and by radiation from the point beyond, without creating any back-reflection effects.

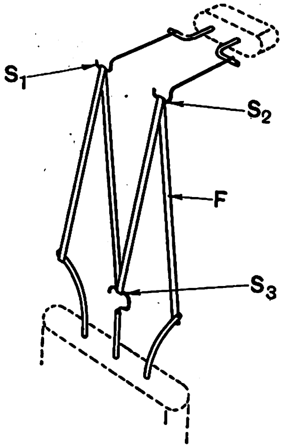
If the loading point is located some considerable distance away from the power house, the system is equivalent to a Beverage or wave aerial, but since no physical "earth" is required, the antenna may be erected vertically. On the other hand, if the loading point is situated relatively near the power house, then the intervening line functions simply as a feeder to the main radiating portion, which may be expanded into any desired form (for example to give directional effects) and erected at a considerable height above the ground.

Patent issued to C. S. Franklin.

VALVE FILAMENTS.

(*Application date, 3rd September*, 1926. *No.* 281401.)

In order to reduce the internal impedance or A.C. resistance of a valve, the filament *F* is made of strip material, and the various legs forming the complete M- or W-shaped filament are all kept in the same plane relatively to the anode, care being taken to see that no out-of-plane twist is introduced at the bight portion where the strips pass over the supports S_1, S_2, S_3. In this way the active or electron-emitting surface of the entire filament is maintained substantially equidistant from the flattened anode.



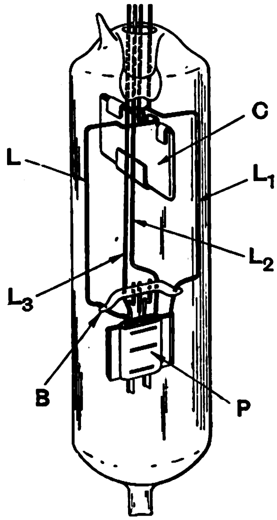
Patent issued to E. Y. Robinson *and* the Metropolitan Vickers Co.

HIGH-FREQUENCY GENERATORS.

(*Convention date* (*U.S.A.*), *17th October*, 1925. *No.* 259937.)

In order to generate oscillations of very high frequency, the effective circuit inductance and capacity is exclusively located inside the bulb of the valve. The grid and filament are enclosed by the plate structure *P*, which is supported by an insulating bridge-piece *B* carried at the extremity of elongated lead-in conductors L—L_3. The lead *L* from the high tension battery to the plate, and the lead L_1 to the grid, are respectively bent outwards to form an inductive loop as shown.

The corresponding tuning capacity is contributed in part by the inter-electrode or grid-plate capacity, and in part by a small condenser *C* mounted as shown near the stub end of the valve, which also serves to keep the high-tension voltage from the grid. The lead-in conductors are connected to a node in the oscillatory circuit, and are bent back into a plane at right-angles to the inside loop, so as to minimise undesirable inductive effects.



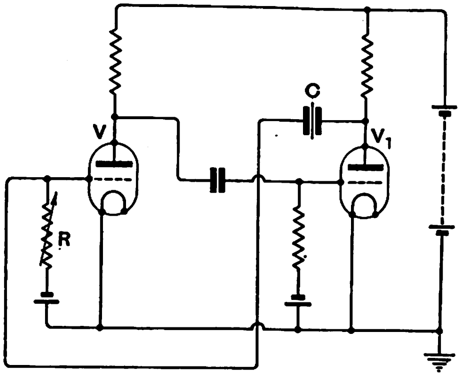
Patent issued to the British Thomson Houston Co.

PIEZO-CONTROLLED VALVE GENERATORS.

(*Application date*, *1st October*, 1926. *No.* 281810.)

In order to generate sustained oscillations, the voltage variations across the grid and filament of a valve must be out of phase with those existing across the plate and filament. In this connection a piezo crystal oscillating at its natural frequency behaves as though it were a pure resistance of the order of, say, 20,000 ohms, whilst at other frequencies the crystal is equivalent to a high impedance, introducing a positive or negative phase-angle according to whether the circuit frequency is above or below the fundamental crystal frequency.

Accordingly if the grid and plate circuits of a single valve are back-coupled through a piezo crystal, oscillations at the fundamental crystal frequency will not be maintained, because at that frequency the crystal functions as a pure resistance and tends to keep the plate and grid voltages in phase. However, by using two resistance-coupled valves, *V*, V_1, and inserting the crystal *C* as a back-coupling link between the grid of the first and the plate of the second, the correct phase-relations are ensured, and the system can be made to oscillate at the fundamental crystal frequency. An adjustable resistance *R* in the grid circuit of the first valve provides a critical control of the regenerative action.

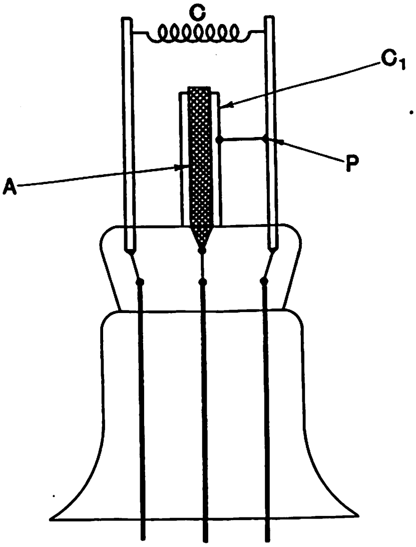


Patent issued to H. L. Kirke.

GAS-FILLED RECTIFIERS.

(*Convention date* (*Germany*), *10th July*, 1926. *No.* 274026.)

A gas-filled thermionic rectifier is characterised by the feature that the distance between the anode and the glowing cathode (or an element connected thereto) is substantially equal to the mean free path of the gas molecules at the working pressure.



As shown in the Figure, the glowing cathode *C* is connected through a lead from the point *P* with a metal cylinder C_1 closely surrounding the anode *A*. The latter is in the form of a thin rod.

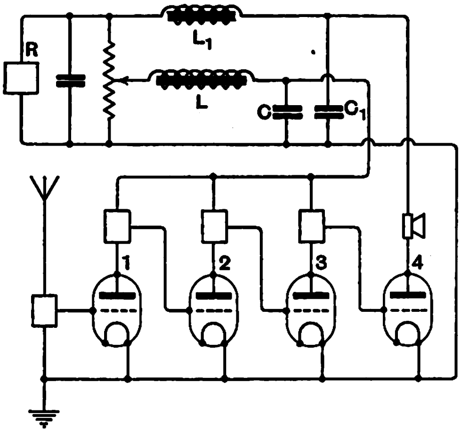
The containing vessel is preferably of metal, or, if of glass, is provided with a mirrored interior which is electrically connected to the cathode in order to stabilise the discharge. It is stated that a rectifier of this type will resist a back pressure of from 500 to 1,000 volts depending upon the enclosed gas, helium giving the best results.

Patent issued to F. Meyer, H. J. Spanner and C. von Wedel.

MAINS-SUPPLY UNITS.

(*Application date*, 10*th September*, 1926. *No.* 281776.)

The combined plate-current taken by, say, the first three stages of a four-valve set, is only a fraction of that consumed in the last or power stage. Moreover, any voltage fluctuations that may persist after the plate supply has been passed through the usual filter circuit will have a much greater effect on the earlier valve stages, where they undergo subsequent amplification, than if they only reach the plate of the power valve.



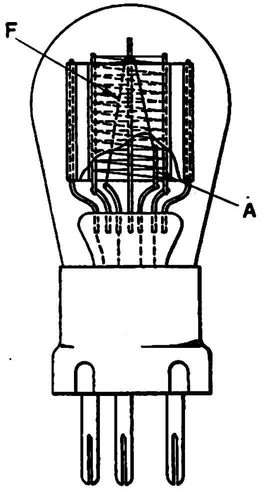
In order to effect an economy in the design of a filter circuit suitable for feeding a multi-valve set, the filter circuit is accordingly divided into two sections, one of high attenuation to carry the supply to the first valves, and the second of lower attenuation to supply the power valve. For instance, the plates of the valves 1, 2 and 3 are fed from the rectifier *R* through a choke *L* consisting of a very large number of turns of fine wire shunted by a condenser *C*. The supply to the plate of the power valve 4, on the other hand, passes through a choke L_1 having fewer turns of heavier-gauge wire, shunted by a condenser C_1.

Patent issued to W. J. Brown and the Metropolitan Vickers Co.

NEUTRALISING SPACE CHARGE.

(*Application date*, 19*th July*, 1926. *No.* 280617.)

The effect of the crowd of electrons normally surrounding the heated cathode of a valve is counterbalanced by deliberately introducing a substance which liberates positive ions under the influence of heat. A suitable material for this purpose is a fused mixture of iron oxide with a small percentage of an alkali or alkaline earth metal, a discovery due to C. H. Kunsman.



As shown in the Figure, a part *A* of the ordinary hair-pin filament *F* is coated with the ion-emitting substance which becomes active under the influence of the filament heating current. The coated leg *A* is connected to the positive terminal of the filament battery, so that the ions, when freed, naturally drift towards the more negative parts of the filament, and thus automatically counterbalance the stagnant electrons accumulated there.

Patent issued to L. J. Davies.

Catalogue Received.

GETTING THE MOST OUT OF RADIO. An educational catalogue of Quality radio components and accessories, distributed by Claude Lyons, Ltd., 76, Old Hall Street, Liverpool. A booklet of 72 pp., price 1s.

This booklet is mainly a detailed catalogue of apparatus handled by Claude Lyons, Ltd. It is prefaced by eight pages of advice on getting the most out of radio by Mr. Claude Lyons. The bulk of the catalogue section of the book is devoted to the products of General Radio Co., of Cambridge, Mass., U.S.A., the remainder dealing with a selected range of components, mostly of American manufacture. It is interesting to have the information so detailed on a number of important products of the General Radio Co., which specialises in the manufacture of testing sets and laboratory equipment to meet the requirements of the wireless trade.

EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. V. APRIL, 1928. No. 55.

Editorial.

Some Further Problems in Potential Difference.

IN our last issue we discussed the question of the meaning of potential difference when applied to alternating current circuits, and we showed that in such cases the ordinary definition of potential difference leads to an ambiguity which can only be removed by adding a proviso to the definition.

The potential difference between two points is still equal to the work done in transferring unit charge from one point to the other, but certain restrictions must be imposed upon the path followed.

We wish now to examine two apparently simple problems, one of which was devised as a trap for junior students of electrical engineering, but in which much bigger game are sometimes found entangled. The first problem will be found in Mather and Howe's "Exercises in Electrical Engineering"; it is as follows: "The North Pole of a magnet is moved towards the open loop *ACB*, as shown in the Figure. Which is at the higher potential, *A* or *B*? The resistance of the loop *AB* is 1 ohm and the ends are joined to form a continuous ring. As the north pole is moved towards it there is at a certain instant a current of 1/20 ampere flowing in it. What is the P.D. at this moment between the joint *AB* and the opposite point *C*?" On moving the magnet pole towards the loop an E.M.F. is induced in the loop tending to drive current around it in an anti-clockwise direction and a small movement of electricity will take place in this direction, charging up the end *A* of the wire positively and the end *B* negatively, thus making *A* at a higher potential than *B*. It is interesting to note the mental process by which many students come to the opposite conclusion; having decided that the current tends to flow in the direction *BCA*, they think that *B* must be at a higher potential than *A*, *because current flows from points at higher to points at lower potential.* Having, by means of a pump, moved water up a pipe from the basement to the attic, they would hardly conclude, however, that the basement was higher than the attic *because water flows from higher to lower levels.*

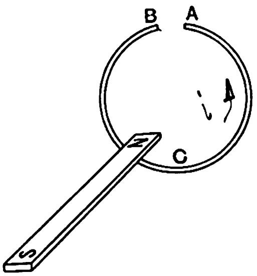


Fig. 1.

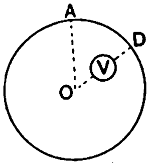


Fig 2.

The second part of the problem is more interesting; the student usually proceeds as follows: A current of 1/20 ampere flows down the left-hand side of the closed ring, and as the whole ring has a resistance of 1 ohm, the joint *AB* must be at a higher potential than *C* by 1/40 volt, but since the current flows up the right-hand side of the ring, the same reasoning leads to the conclusion that *C* has 1/40 volt higher potential than the joint *AB*. This contradictory result compels one to think, and very little thought is required to see that from the symmetry of the arrangement there can be no difference between the electrical condition of different parts of the ring; all points of it are necessarily at the same potential and current is flowing around it, not because of any differences of potential, but because of the electromotive force induced in it equally at every part.

If one wished to measure the P.D. between any two points of the ring, such as *A* and *D* in Fig. 2, the leads to the voltmeter would have to be arranged as shown, that is, radially, and the voltmeter would read zero. If, instead of plunging a permanent magnet into the ring, the changes of flux are produced by varying an electric current in a coil parallel to and co-axial with the ring, it will be seen that the radial voltmeter connections are at right angles to the vector potential. This we have seen to be essential to an accurate measurement of the P.D. in the presence of changing magnetic fields.

The second problem which we wish to consider only differs from the foregoing in that the closed ring is of a dielectric material, such as ebonite instead of copper. On plunging in the permanent magnet or changing the current in the parallel coil, the same electromotive force is induced in the ebonite ring as in the copper ring, but whereas in the latter this caused an electronic stream to flow around the ring, in the former the electrons are only capable of limited elastic displacement from their normal positions. On the application of the E.M.F., something happens in the ebonite, the exact nature of which is not known, but which is almost undoubtedly an elastic movement or displacement of electrons in their atomic orbits. The electric force **E** in the material is obtained in volts per cm. by dividing the total induced E.M.F. in volts by the total length around the ring in centimetres. If a sufficiently great magnetic flux could be changed at a sufficiently great rate, the electric force in the ebonite would presumably break it down.

Now arises the interesting question: is there any difference of potential between different parts of the ebonite ring during the time that the magnetic flux is changing? As in the copper ring it can be seen from the symmetry of the arrangement that there can be no difference between the electric condition of different parts of the ring, and there is no reason why one part should be at any higher or lower potential than any other part. If a voltmeter be properly connected between any two points of the ring, as shown in Fig. 2, the voltmeter will show no potential difference. The mental process by which people sometimes arrive at the opposite conclusion is very similar to that already described for the copper ring and is equally fallacious.

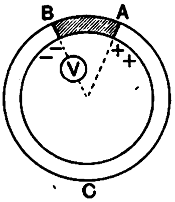


Fig. 3.

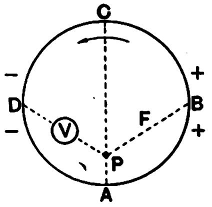


Fig. 4.

We see, therefore, that an electric force or stress in a dielectric may exist without any potential gradient, and that the force may be so great that the dielectric is broken down, although all parts of it are at the same potential. On the other hand, electric force in a dielectric may be, and often is, due to a potential difference. If in Fig. 3 the larger part *ACB* of the ring is made of copper and the smaller part *BA* of ebonite, and the north pole of a magnet is plunged symmetrically into it as in Fig. 1, the same E.M.F. will be induced in it. A momentary current will flow in the copper causing an excess of electrons in the part near *B* and a deficit in the part near *A*. This produces a difference of potential between *A* and *B*, which would be indicated on a voltmeter connected up as shown. Corresponding to this P.D. there will be an electric field both in the copper and in the ebonite, as well as in the surrounding air in the direction from A to B. In the copper the two electric fields, viz., that due to the magnetic induction and that due to the accumulated charges, are in opposition, and the distribution of charges will automatically adjust itself so that the latter, which we may call the electrostatic force, is equal and opposite at every point to the magnetically induced electric force, thus giving zero resultant electric force at every point within the conductor.

In the ebonite section, however, the state of affairs is entirely different; here the electrostatic force due to the accumulated charges at A and B is in the same direction as the magnetically induced electric force, giving a resultant electric force equal to their sum at every point. Moreover, since the resultant force in the copper is zero, that in the ebonite is equal to the total induced E.M.F., divided by the length of path in the ebonite. Hence the total induced E.M.F. acts on the ebonite, that part which is primarily induced in the copper being transferred to the ebonite as a P.D. between its ends. To obtain the electric force in the ebonite one must add to the potential gradient the electric force directly induced in it.

Returning to the ring of copper wire, we shall now consider the effect of plunging the magnet pole into the coil unsymmetrically. In Fig. 4 let P represent the pole entering the coil; the dotted lines may represent lines of force or they may represent lines normal at every point to the vector potential at the point, and therefore the lines along which voltmeter leads must be taken to obtain readings of the P.D. between any points on the ring. If the leads follow other paths electromotive forces will be induced in them which may vitiate the readings. Although the electric force induced in the wire at A is larger than that induced at C, the current is necessarily the same at every part of the ring once the steady state has been established. Since the electrons at A are moving no more rapidly than those at C, they must be subjected to the same force. This apparent contradiction is explained at once by the positive and negative charges which accumulate on the right- and left-hand sides of the ring, as shown in Fig. 4. These charges produce electrostatic forces opposing the induced forces in the lower half and assisting them in the upper half of the ring. The charges will automatically distribute themselves over the ring in such a way that the electrostatic forces exactly counterbalance the inequalities in the magnetically induced force, thus producing a uniform electric force in agreement with the uniform current.

There is now a P.D. between any two points on opposite sides of the line AC. A and C are at the same potential. A voltmeter connected as shown between the points D and B will correctly read the P.D. between these two points if the leads are run *via* $DVPFB$. The P.D. could be calculated for any given conditions; assume, for example, in Fig. 4 that the pole P is passing through the plane of the coil, and that the angle subtended at P by DAB is $\frac{5}{8}$th, and that subtended by DCB is $\frac{3}{8}$th of 360 degrees; then if E is the total E.M.F. induced in the ring at this moment, the E.M.F.s induced in DAB and BCD are $\frac{5}{8}E$ and $\frac{3}{8}E$ respectively, and since the IR drop is $\frac{1}{2}E$ in each half of the ring, the P.D. between B and D is equal to $\frac{5}{8}E-\frac{1}{2}E$ or to $\frac{1}{2}E-\frac{3}{8}E$, depending on whether one considers the bottom or top half. Hence the P.D. between B and D is $\frac{1}{8}E$.

If Fig. 4 be taken to represent a ring of some dielectric material such as ebonite the displacement at A will be greater than that at C, with the result that the ring will become charged somewhat as shown. The effect of the charges will be to diminish the electric force at A and to increase that at C, but their distribution on the ring will not be the same as in the copper ring, since the resultant electric force is not constant around the ring, but depends on the displacement, the variation of which causes the distribution of the electric charge. The conditions are thus much more complicated than in the case of the copper ring. A voltmeter connected as in Fig. 4 will, however, correctly read the P.D. between the points D and B.

These phenomena occur because the dielectric constant or specific inductive capacity of the ring differs from that of the surrounding medium. If it did not the ring would not differ electrically from the surrounding medium, and the displacement at every point would be proportional to the magnetically induced electric force at that point. The dielectric constant ϵ of the ring material can be regarded as consisting of two parts 1 and $\epsilon-1$, the former being that which the space would have if the ring were not present and the latter the additional part due to the ring material. The former component has no disturbing effect on the concentric displacement produced by the magnetically induced electric force which would exist in the absence of the ring, and we need not consider this component any further. Any charges on the ring and any potential differences must be due to the latter component $\epsilon-1$, which one must therefore employ in calculating them. These effects will become vanishingly small as ϵ approaches unity.

These problems in the electric potential of dielectric rings have their parallel problems in magnetic potential, the case just considered being very analogous to that of the iron toroid with a winding on one part of it, whilst the case of the symmetrically-induced ring is analogous to the uniformly wound toroid in which there is no difference of magnetic potential and consequently no leakage field.

The questions which we have considered in this and the previous article are fundamental to a proper understanding of electric circuits.

One's difficulties with the electric problems may be cleared up by considering a simple mechanical analogy. The ring is represented by a circular groove or canal cut in a horizontal surface and filled with water to represent a conductor or with jelly fastened to the sides of the groove to represent a dielectric. If a portion of the canal is filled with jelly and the remainder with water it will represent the copper and ebonite ring of Fig. 3.

The electromotive force must be replaced by a material-moving force, such as a circular draught of air, which might be produced by a large number of slanting nozzles just above and all round the canal or by a disc rotating at a high speed and fitted with vanes just above the canal.

A consideration of the difference of pressure or of level between different points of the canal will help to remove any difficulties which one may still have with the electric problems.

G. W. O. H.

The Approximate Theory of the Screen-grid Valve.

By B. C. Brain, B.Sc. (Hons.).

THE object of this paper is to show how the general shape of the characteristic curves and the static constants, viz.: amplification factor, differential anode resistance, mutual conductance, and inter-electrode capacity can be predicted from consideration of the structural constants in the special type of four-electrode valve called the screen-grid valve.

The constants of these valves differ from those of triodes in three principal ways:—

(1) The capacity between grid and anode is very much less.

(2) The mutual conductance is very much higher than is possible in a triode using the same filament and having the same amplification factor.

(3) The amplification factor of a screen-grid valve is not a structural constant, as in the triode, but depends largely on the anode and screen-grid voltages.

Although the writer does not propose to consider the screen-grid valve as a circuit element, it is essential to observe that for high amplification the quantity

$$\frac{\text{Amplification Factor}}{\sqrt{\text{Differential Anode Resistance}}}$$

should be as high as possible assuming ideal circuit conditions.* In general this increases with the anode resistance, but in practice if this is made very high it is impossible to even approximate to ideal conditions.

Van der Bijl and other investigators have shown that the space current in any triode can be calculated by finding the resultant potential in the plane of the grid due to the plate potential and the grid potential, and then treating the case as a hypothetical diode with its anode in the plane of the control grid, and having an anode potential equal to the resultant potential acting in the plane of the grid of the triode. Further, he showed that the anode potential E_a could be replaced by a potential $\frac{E_a}{m}$ acting in the plane of the grid, so that the resultant effective potential is

$$\frac{E_a}{m} + E_g.$$

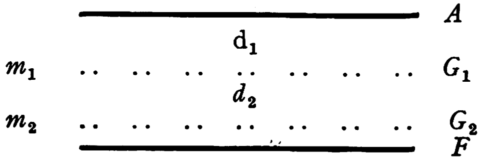
Hence the space current in a triode is given by

$$I = K\left(\frac{E_a}{m} + E_g\right)^{\frac{3}{2}} \quad .. \quad (1)$$

K is a constant which depends only on the structure of the grid and filament. It can be obtained by calculation in special cases, but owing to uncertainty in the active length of filament and the effect of initial velocity of emission of the electrons, it is generally preferable to obtain the value of K experimentally.

In the case of the screen-grid valve we have to find the effective voltage in the plane of the control grid due to the combined effects of the screen-grid and anode potentials.

Let us consider a valve having a filament system F, and, parallel to the plane of the filament, the control grid G_2, screen grid G_1 and anode A. The grids are considered to extend to infinity, so that there is no question of leakage of electrons round the sides of the grids or imperfect shielding.



Let d_1 be the distance of the grid G_1 from the anode.

Let d_2 be the distance of the grid G_2 from the grid G_1.

In equation (1) m is the voltage factor of the grid with respect to the anode. In the screen-grid valve we have two grids both of which must have a voltage factor.

Let m_1 be the voltage factor of G_1 with respect to A.

---

* V. G. Smith, *Inst. Rad. Eng. Proc.*, 15, pp. 525–536, June, 1927.

Let m_2 be the voltage factor of G_2 with respect to G_1.

We have then an effective potential $\frac{V}{m_1}$ acting in the plane of the screen grid due to the anode potential, so that we can consider the tetrode as replaced by a triode with an anode potential of $\frac{V}{m_1} + V_1$, so far as the space current is concerned. V_1 is the screen-grid potential. Hence from equation (1) we have

$$I = K\left[\frac{V}{m_1 m_2} + \frac{V_1}{m_2} + E_g\right]^{\frac{3}{2}} \quad .. \quad (2)$$

This gives us the total current leaving the filament. Since the screen-grid potential V_1 is positive with respect to the filament, a fraction I_g will be collected by the screen-grid, and the remainder I_a will reach the anode.

For the purposes of screening, m_1 is large compared with m_2, so that the current leaving the filament is practically determined by the screen-grid voltage. Hence the space current in a screen-grid valve is roughly the same as that of a triode of the same dimensions having its anode in the plane of the screen grid.

Let us assume for the present that all the electrons which strike the grid or anode are immediately absorbed, also that sufficient grid bias is applied to prevent current flowing in the control grid circuit.

Thus:

$$I = I_a + I_g \quad .. \quad .. \quad (3)$$

where I_a and I_g are respectively the anode and screen grid currents.

It can be shown that when m_1 is high the number of electrons striking the screen grid is nearly independent of V and is proportional to the ratio of the projected areas of grid and anode. Hence if there are n_1 grid wires per unit length of radius r_1, we have

$$\frac{I_g}{I_a} = \frac{2r_1 n_1}{1 - 2r_1 n_1} = p \quad .. \quad (4)$$

From equations (2), (3), and (4), we get

$$I_a = \frac{1}{1+p} \cdot K\left[\frac{V}{m_1 m_2} + \frac{V_1}{m_2} + E_g\right]^{\frac{3}{2}}. \quad (5)$$

$$I_g = \frac{p}{1+p} \cdot K\left[\frac{V}{m_1 m_2} + \frac{V_1}{m_2} + E_g\right]^{\frac{3}{2}}. \quad (6)$$

From equation (5) we get, when $E_g = 0$,

Amplification Factor.

$$M = m_1 m_2 \quad .. \quad .. \quad .. \quad .. \quad (7)$$

Mutual Conductance.

$$G = \frac{3}{2} . K . \frac{1}{1+p} . \left[\frac{V}{m_1 m_2} + \frac{V_1}{m_2}\right]^{\frac{1}{2}} .. \quad (8)$$

Differential Anode Resistance.

$$R_a = \frac{2}{3}\,\frac{1+p}{K} . m_1 m_2\left[\frac{V}{m_1 m_2} + \frac{V_1}{m_2}\right]^{\frac{1}{2}} .. (9)$$

Inter-electrode Capacity and Voltage Factor.

Owing to the fact that in order to allow the electrons to reach the anode it is impossible to use a solid shield grid, there are lines of force between the anode and control grid which can never be completely eliminated. In order to calculate the resultant grid to plate capacity we shall make use of a result obtained by Maxwell in the course of his investigations on electrostatic screening.*

We shall assume that the capacity between the grid and plate is the same as would be obtained if G_2 were solid. This assumption is justified so long as the grid wire spacing of G_2 is small compared with the distance d_2. When this is no longer true, the capacity calculated will clearly be higher than the actual capacity.

Let the surface density of charge on G_2 be σ when the anode, screen grid and control grid are maintained at potentials V, V_1, and E_g respectively.

According to Maxwell

$$4\pi\sigma\left(d_1 + d_2 + \frac{d_1 d_2}{a}\right) = \left(1 + \frac{d_1}{a}\right)E_g - V - \frac{d_1}{a}V_1 \; .. \quad (10)$$

where $\quad a = -\frac{1}{2\pi n_1}\log_e(2\sin \pi n_1 r_1)$.

Differentiating (10) with respect to σ and treating V_1 and E_g as constants, we have

$$\frac{\delta V}{\delta\sigma} = -\,4\pi\left(d_1 + d_2 + \frac{d_1 d_2}{a}\right) \; .. \quad (11)$$

---

* J. C. Maxwell, "Electricity and Magnetism," Vol. 1, p. 310.

Similarly, by differentiating with respect to V_1, we have

$$\frac{\delta\sigma}{\delta V_1} = \frac{d_1}{a} \cdot \frac{1}{4\pi\left(d_1 + d_2 + \frac{d_1 d_2}{a}\right)} \quad .. \quad (12)$$

From (11) and (12), we get King's result* for the voltage factor of G_1 with respect to A

$$m_1 = \frac{\delta V}{\delta\sigma} \cdot \frac{\delta\sigma}{\delta V_1} = \frac{d_1}{a} = -\frac{2\pi n_1 d_1}{\log_e (2 \sin \pi n_1 r_1)}.$$

If we assume that r_1 is small compared with the wire spacing $\frac{1}{n_1}$ this can be rewritten

$$m_1 = -\frac{2\pi n_1 d_1}{\log_e 2\pi n_1 r_1} \quad .. \quad .. \quad (13)$$

Also the capacity is $\frac{\delta\sigma}{\delta V}$; hence from (11) putting a in terms of m_1 we have

$$C = \frac{1}{4\pi(d_1 + d_2 \cdot \overline{1 + m_1})} \quad .. \quad (14)$$

per unit area.

When the screen-grid is removed, *i.e.*, $m_1 = 0$, we have the well-known result for a parallel plate condenser in vacuo.

Equation (14) means that the effect of the screen-grid is the same as would be produced by increasing the distance between anode and grid in any valve by m_1 times the distance between the two grids. Since d_1 is small compared with $m_1 d_2$ we can say that :—

The capacity is almost inversely proportional to the distance between the screen-grid and control-grid.

Secondary Emission Effects.

We have so far assumed that the only current which reached the anode and screen-grid originated from the filament. This is not justified, however, since the electrons striking the surface of the screen grid and anode dislodge other electrons. Thus, if the anode voltage is higher than the screen-grid voltage, secondary electrons from the grid G_1 will be attracted to the anode. Conversely, if the screen-grid voltage is the higher, secondary electrons from the anode will reach the screen grid.

We shall, in this paper, only deal quantitatively with the first case, as it is the one which is most frequently met in practice.

The flow of secondary electrons will, of course, be limited by the space-charge due to both primary and secondary electrons. Since the primary electrons will be moving with very high velocities in the neighbourhood of the screen grid, we can safely neglect their space charge. The result of the secondary space charge is that a certain difference of potential will be required to draw all the secondary electrons from the emitting to the collecting electrode. The secondary current i will, therefore, behave in the same way as an ordinary thermionic current in a plane parallel type diode having its electrodes in the planes of screen-grid and anode. When the difference of potential is insufficient to collect all the secondary electrons the current is nearly independent of the total secondary emission, but depends on the distance apart of the electrodes, their effective area, and the field acting between them. When all the secondary electrons are collected the secondary current is equal to the total secondary emission and is independent of the field acting between the electrodes or the distance between them.

Case I. Total Secondary Emission.

The experimental results of investigators, notably Farnsworth,* show that the laws governing the rate of emission of secondary electrons are extremely complicated. When the impinging electrons have a low velocity the emission seems to follow no simple law, but above about 10 volts the curve is approximately a straight line, showing that the ratio of the secondary current to the primary current is proportional to the accelerating potential acting on the primary electrons.

We shall, therefore, assume that the emission of secondary electrons follows the law

$$\begin{aligned} i &= K^1 \cdot I_g(V_1 - V_0) \\ &= K^1 \cdot p \cdot (V_1 - V_0) \cdot I_a \quad .. \quad (15) \end{aligned}$$

where K^1 and V_0 are constants depending on the nature of the surface of the screen-grid. This depends very largely on the method of exhaust and the heat treatment given to the surface during exhaust. A getter of magnesium is commonly used in valves of this type, and for a grid in a valve using this getter, the constants are of the order of $K^1 = .01$ and $V_0 = 15$ volts, although valves of the same type show considerable variations from these values. It is possible by specially coating the surface to raise K^1 as high as .05 and also to slightly reduce V_0.

---

* R. W. King, paper read at October, 1919, meeting of *Am. Phys. Soc.*, Philadelphia.

* H. E. Farnsworth, *Phys. Rev.*, 20, 358, 1922; H. E. Farnsworth, *Phys. Rev.*, 25, 41, 1925; H. E. Farnsworth, *Phys. Rev.*, 27, 413, 1926.

The anode current will now be increased by an amount i given by equation (15) and the grid current reduced correspondingly. This, of course, represents a reduction of waste high tension battery current.

$$I_a + i = \frac{1}{1+p} \cdot K\left[\frac{V}{m_1m_2} + \frac{V_1}{m_2} + E_g\right]^{\frac{3}{2}} (1 + pK^1 \cdot \overline{V_1 - V_0}) \quad .. (16)$$

$$I_g - i = \frac{p}{1+p} \cdot K\left[\frac{V}{m_1m_2} + \frac{V_1}{m_2} + E_g\right]^{\frac{3}{2}} (1 - K^1 \cdot \overline{V_1 - V_0}) \quad .. (17)$$

Equations (7), (8), and (9) thus become

$$M = m_1m_2$$

$$G = \frac{3}{2} \cdot \frac{1}{1+p} \cdot K\left(\frac{V}{m_1m_2} + \frac{V_1}{m_2}\right)^{\frac{1}{2}} (1 + pK^1 \cdot \overline{V_1 - V_0}) \quad .. (18)$$

$$R_a = \frac{2}{3} \cdot \frac{1+p}{K} \cdot m_1m_2 \cdot \left(\frac{V}{m_1m_2} + \frac{V_1}{m_2}\right)^{-\frac{1}{2}} (1 + pK^1 \cdot \overline{V_1 - V_0})^{-1} \quad .. (19)$$

The result, therefore, of a *saturated* secondary current from the screen grid to the anode is to reduce the "R_a" without affecting the "M," thus improving the mutual conductance.

Supposing the "G" previously calculated for a valve was .5 milliamp per volt, then taking $p = .4$ and $V_1 = 80$ volts, the new value of "G" for an average valve would be increased to .63 milliamp per volt, and if the grid were specially treated to give a high secondary emission "G" *might be raised to* 1.2. In this case the screen-grid current would be negative and there would be no wastage of battery current.

There is, however, a very serious obstacle to the attainment of this sort of result. It is that, in practice, impossibly high values of $V - V_1$ have to be used to secure saturation of the secondaries. The most probable explanation of this effect is the theory that was put forward by Langmuir to explain the lack of saturation obtained with oxide coated or thoriated filaments. It can be shown that it is easier for an electron to escape from a sharp point than from a smooth flat surface. Thus, if an emitting surface is irregular in contour the bulk of the current will originate from the peaks. With an increase of field between the electrodes a larger proportion of current will flow from the hollows, and, so as the field is increased, the effective area of the cathode increases and the current increases.

Since in the case we are considering the emitting surface is a grid, it is to be expected that this effect would take place.

Case II. The Secondary Current is Less than Saturation.

The secondary current under these conditions is difficult to estimate since we know very little about the emitting area of the screen-grid. We shall, therefore, investigate the effect of an unsaturated secondary current qualitatively.

Since the secondary current is independent of the total secondary emission, it is independent of the control grid potential, and hence the mutual conductance is unaltered by secondary emission so long as the secondary current is considerably below saturation point. As the secondary current is affected by the total secondary emission at a considerable distance below the bend on the $i/(V - V_1)$ curve, we shall expect a gradual increase in mutual conductance until saturation is reached. We can, however, consider under Case II that G is constant.

The anode conductance $\frac{1}{R_a}$ is the sum of the primary and secondary electron conductances.

Thus if

$$\frac{dI_a}{dV} = X \quad \text{and} \quad \frac{di}{dV} = Y$$

the R_a is

$$\frac{1}{X + Y}$$

$$= \frac{1}{X} \cdot \frac{1}{1 + \frac{Y}{X}}$$

Now $\frac{1}{X}$ is the anode resistance given by equation (9) neglecting secondary emission, so that the R_a is modified by the factor

$$\frac{1}{1+\frac{Y}{X}}.$$

When the secondary emission is unsaturated, it is clear from the construction that the secondary electron conductance must be very high compared with the primary conductance, hence $\frac{Y}{X}$ is large compared with 1 and hence the resultant R_a is much lower than the value $\frac{1}{X}$. As the secondary current approaches saturation, the conductance Y becomes smaller, *so that the R_a increases as the secondary current approaches* saturation, the final value being given by equation (20).

The amplification factor is given by

$$M = m_1 m_2 \frac{1}{1+\frac{Y}{X}}$$

so that the amplification factor will vary in the same way as the R_a, approaching a limiting value given by equation (19) when the secondary current is saturated.

General Conclusions from the Preceding Investigation.

(1) The residual *capacity* between plate and control grid is equal to the capacity between the control grid and screen divided by the " M " of the screen-grid.

(2) The maximum *amplification factor* of a screen-grid valve is the product of the " M's " of the two grids. When there is a secondary emission from the electrodes, the amplification factor is lower than this value. As the difference between the anode and screen-grid voltages increases, the " M " rises asymptotically to the maximum value when the secondary electrons are removed to the anode as quickly as they are emitted.

(3) The *mutual conductance* of a screen-grid valve is equal to that of the corresponding triode (*i.e.*, treating the screen grid as an anode), minus a percentage due to the electrons intercepted by the screen grid. Thus the " G " falls off rapidly as the screen grid mesh is made very close. This percentage reduction can be lowered and even made negative by treating the grid to obtain a high secondary emissivity. The slope of the I_a/E_g curves (when $E_g = 0$) is very nearly independent of the anode voltage and varies with the screen grid voltage and " M " of the control grid in the same way as in a triode.

(4) The *differential anode resistance* is the ratio of the amplification factor to the mutual conductance as in a triode. Since the slope at constant screen-grid voltage is very nearly constant, it follows that the anode resistance varies with the anode voltage in the same way as the amplification factor.

The simple theory outlined above does not pretend to be exhaustive, but the results are in general agreement with the facts as stated by Hull and others.*

My thanks are due to the British Thomson-Houston Co. for facilities in the experimental verification of some of the theoretical results.

---

* A. W. Hull, *Phys. Rev.*, 27, 439, 1926.
P. T. Beatty, *E.W. & W.E.*, October, 1927.

Mutual Inductance in Radio Circuits.

By L. Hartshorn, A.R.C.S., B.Sc., D.I.C.

(National Physical Laboratory.)

MUTUAL inductance, which is nothing more or less than magnetic coupling, exists in all radio circuits, since almost any two coils or even wires possess a certain definite mutual inductance depending on their position with respect to each other. Thus, if I_p is the current in one wire or coil, then there is an E.M.F. induced in the other wire or coil given by

$$E_s = j\omega M I_p \quad \ldots \quad \ldots \quad (1)$$

where $\omega = 2\pi \times$ frequency, M is the mutual inductance of the two coils or wires, and j is the operator rotating through a right-angle, thus indicating in (1) that the induced E.M.F. (E_s) is in quadrature with the primary current I_p. The simplicity of this equation suggests that mutual inductance should be very useful in radio measurements. For example, it provides a means of obtaining an E.M.F. of any desired amount. A variometer, or two coils, one of which is movable, provides a mutual inductance which is easily variable. If then a definite current I_p is passed through one coil, an E.M.F. given by (1) is induced in the other coil, and the value of M can be adjusted until an E.M.F. of the required value is obtained. This scheme is readily workable at low frequencies, but all who have attempted to use a variometer for measurements of this nature at high frequencies will know that the matter is, not so simple. Distributed self capacities of the two coils, and distributed mutual capacity between the coils, complicate matters considerably. In fact equation (1) only holds for the ideal "pure" mutual inductance. In the present article it is proposed to collect together the most useful properties of the ordinary "impure" mutual inductance, and to point out their bearing on the most common forms of mutual inductance in radio work, *viz.*, variometers, coils with tapped points, and transformers.

The General Case.

The distributed self and mutual capacities of two coils may be represented to a first approximation by lumped capacities connecting the ends of the coils. Thus a mutual inductance formed by two coils AB and CD should be considered as consisting of the network shown in Fig. 1, which was first given by Butterworth.* We have to reckon with six capacities, the self-capacities k_1, k_2 of the two coils, and the four cross-capacities k_3, k_4, k_5, k_6. The properties of this system are rather complicated, and in practice it is usually advisable to simplify it by making one point of the primary, and one of the secondary, common. Thus let the points A and E be connected together. The capacity k_3 is now short-circuited and disappears, k_1 and k_6 are thrown in parallel, and may be represented by a single capacity C_1, k_2 and k_5 similarly form the single capacity C_2, and we have the system of Fig. 2 in which $C_{12} = k_4$. We have now only three capacities, a single cross capacity C_{12}, and the two effective self capacities C_1 and C_2. (These are evidently larger than the self capacities k_1 and k_2 of the coils when far removed from each other.) In the paper already referred to, Butterworth has given a convenient method for the mathematical investigation of the properties of this network, and has deduced a number of useful formulæ. A paper by the present writer,† following up Butterworth's work, deals with some additional properties. The most useful of the formulæ will be quoted here. For proofs the original papers should be consulted.

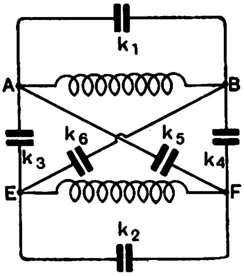


Fig. 1.

Mutual Inductance Equations.

Let the coil AB carry alternating current of frequency $\omega/2\pi$. Owing to distributed capacities, the current will not have the same value in every element of the coil, and therefore the exact value to be assigned to "the current passing through the coil" is a matter for definition. The only currents we can measure directly are those flowing into the terminal A, or out of the terminal B. These two currents will have the same value provided earth capacity effects are negligible, and when we say that a current I_p flows through the coil, this terminal current is the one referred to. Referring to Fig. 2, I_p will evidently include the current through C_1.

---

* Butterworth, *Proc. Phys. Soc.*, Vol. 33, p. 313, 1921.

† Hartshorn, *Proc. Phys. Soc.*, Vol. 38, p. 303, 1926.

Let L_1 and R_1 be the self-inductance and resistance of the primary coil AB, L_2 and R_2 those of the secondary coil AF, and M_0 be the geometrical mutual inductance of the two coils. This is the value of the mutual inductance obtainable by calculation from the dimensions of the coils, the number of turns, and their position with respect to each other. It is practically the same as the value measured at low frequencies.

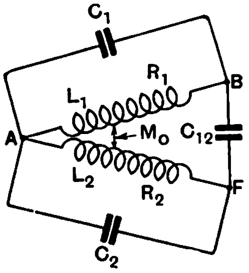


Fig. 2.

The potential difference developed at the secondary terminals is now given approximately by

$$V_s = (\sigma + jM\omega)\, I_p$$

where

$$M = M_0 + \Delta M = M_0 + C_{12}R_1R_2 + \omega^2\{C_1L_1M_0 + C_2L_2M_0 - C_{12}(L_1 - M_0)(L_2 - M_0)\} \quad ..(3)$$

$$\sigma = \omega^2[C_1R_1M_0 + C_2R_2M_0 - C_{12}\{R_1(L_2 - M_0) + R_2(L_1 - M_0)\}] \quad ..(4)$$

Equation (1) gave the secondary E.M.F. (E_s) in the ideal case. Equations (2), (3), (4) give the secondary P.D. (V_s) which is observed in practice. This is not quite the same as the E.M.F. actually induced in the secondary coil, but as the P.D. is the only quantity we can measure, it alone need be considered. This P.D. is no longer exactly in quadrature with the current I_p. There is an in-phase component σI_p which is proportional to the square of the frequency, and which may thus become very important at radio frequencies. Further, the effective mutual inductance M differs from its value at low frequencies (M_0) by an amount ΔM which is proportional to the square of frequency.

From (3)

$$\Delta M = \omega^2\{C_1L_1M_0 + C_2L_2M_0 - C_{12}(L_1 - M_0)(L_2 - M_0)\}$$

These "frequency" effects all increase with increasing capacities.

It must be borne in mind that the direction of the E.M.F. induced in a coil is reversed if the direction of winding of the coil is reversed. Thus a mutual inductance M can be regarded as possessing either a positive or a negative sign. In equations (3) and (4) a positive sign must be given to M_0 if the direction of winding is such that the mutual inductance opposes the self-inductance of the two coils when current is passed through the combination via the open ends.

Application to Variometers.

In a mutual variometer for use in radio measurements it is desirable that the effective mutual inductance at any point of the scale should have a definite constant value for all working frequencies, and that as the moving coil is turned, the effective mutual inductance should decrease to zero. Equation (3) shows that owing to capacity effects, the effective mutual inductance contains a term which is proportional to the square of the frequency, and therefore it is essential that this term be made small if the instrument is to have a constant calibration for all frequencies. This frequency term consists of the difference of the two self-capacity terms

$$C_1L_1M_0 + C_2L_2M_0$$

and the mutual capacity term

$$C_{12}\,(L_1 - M_0)\,(L_2 - M_0).$$

Now generally $L_1 > M_0$ and $L_2 > M_0$ numerically. Thus, provided the direction of winding is such as to make M_0 positive, the effect of mutual capacity opposes that of self-capacity. If, however, the other direction of winding is used the "frequency coefficient" or ΔM becomes much larger, since the mutual capacity effect is added to that of self-capacity. For this reason if a scale showing both + and − mutual inductance is used, it is not likely to be quite symmetrical about the zero point. It is evident by inspection of the expression for the frequency coefficient that the conditions to be satisfied by a good design are :—

1. The coils should be as small in self-inductance as possible.
2. They should possess self-capacities as low as possible.
3. The primary and secondary coils should be connected together at one end, and where possible the direction of winding should be such as to make the mutual inductance oppose the self-inductance.

Conditions (1) and (2) make the terms $C_1L_1M_0$ and $C_2L_2M_0$ small. Condition 3 makes the term $-C_{12}(L_1-M_0)(L_2-M_0)$ of opposite sign to $C_1L_1M_0$ and $C_2L_2M_0$, if, as is usual, M_0 is less than L_1 and L_2. It is interesting to note that screening, which may be carried out by interposing an earthed "resistance net" between the two coils, will not reduce the "frequency effects" to zero, since although it may make $C_{12} = 0$, it may increase the values of C_1 and C_2 considerably. The impurity "σ" is usually less important than ΔM, since it depends largely on the resistances R_1 and R_2, and these are always made as small as possible. Butterworth has shown that σ may be largely increased by eddy current effects, and on this account it is necessary to use stranded wire. When the two coils are set in their conjugate position so that M_0 is zero, we see from (3) that the effective mutual inductance is

$$C_{12}R_1R_2 - \omega^2C_{12}L_1L_2,$$

of which the first term is always negligible. The value of σ in this case is

$$-\omega^2C_{12}(R_1L_2 + R_2L_1)$$

and thus the secondary P.D. is (approx.)

$$V_s = -\omega^2C_{12}\{R_1L_2 + R_2L_1 + j\omega L_1L_2\}.$$

Thus the secondary P.D. cannot be reduced to zero unless C_{12} is reduced to zero by perfect screening, and the minimum secondary P.D. will increase rapidly with increase of frequency and of self-inductance of the coils.

Effective Resistance Equations.

Referring again to Fig. 2 the effective resistance of this network between the points AB is shown by Butterworth to be approximately

$$R_1[1 + 2\omega^2\{C_1L_1 + C_{12}(L_1 - M_0)\}] \qquad (5)$$

Similarly the effective resistance between the points AF is

$$R_2[1 + 2\omega^2\{C_2L_2 + C_{12}(L_2 - M_0)\}] \qquad (6)$$

and it is easy to show that the resistance between the points BF is approximately

$$R_1 + R_2 + 2\omega^2[R_1L_1C_1 + R_2L_2C_2 + C_{12}(R_1 + R_2)(L_1 + L_2 - 2M_0)] \qquad (7)$$

Equations (5) and (6) give the effective resistance of a coil which is connected to a second coil magnetically coupled to it, the ends of the second coil being left open.

An inductance coil with a tapped point is a common example of such a system, and the equations show at once the "dead end" effect in the case of a coil BAF, of which the portion BA is tapped off. The resistance of the portion BA in the absence of AF is $R_1(1 + 2L_1k_1\omega^2)$ approx. When AF is present the effective resistance is given by (6), but in this case the sign of M_0 must be taken as negative, since the mutual inductance of the two parts of the coil always adds to the total self-inductance. Thus the numerical value of the "dead-end" effect is $2\omega^2R_1\{L_1(C_1 - k_1) + C_{12}(L_1 + M_0)\}$. The capacity C_1 (Fig. 2) is the resultant of k_1 and k_6 (Fig. 1), but $(C_1 - k_1)$ is nearly always less than k_6, since the capacities k_1 and k_6 represent electrostatic actions across dielectric paths which are partly coincident, so that they are not strictly additive.

A point to be noted is that if we have two coils BA and AF in series, their total resistance given by (7) is not exactly equal to the sum of their individual resistances given by (5) and (6). In fact, if the individual resistances are R_α and R_β it may be shown that the total resistance is

$$R_\alpha + R_\beta - 2\sigma \qquad .. \; (8)$$

where σ is given by equation (3). (This is exactly analogous to the expression for the total inductance $L_\alpha + L_\beta - 2M$.) The expression (8) only holds when the individual resistances R_α and R_β are measured with both coils in position. If the coils are separated the self-capacities again become k_1k_2, as in Fig. 1, and thus the effective resistances are altered. These points must be borne in mind in applying the method of measuring the effective resistances of condensers due to Prof. R. R. Ramsey and described by C. D. Callis.* It is evident that the quantity 2σ in (8) represents the error of the method when these effects are overlooked as was done by the original author.

---

* C. D. Callis, *Phil. Mag.*, Series 7, Vol. 1, p. 428, 1926.

Self-capacity Equations.

Consider again an inductance coil with a tapping point. When part of the coil only is being used, the rest of it acting as a "dead-end" increases the effective self-capacity of the coil, and the amount of this may be expressed as follows. Represent the coil by Fig. 2 so that BAF is the complete coil, and A the tapping point, L_1 and L_2 are the self-inductances of the two parts and $L_1 + L_2 - 2M_0$ is the total self-inductance. (In accordance with the usual convention M_0 must be regarded as negative for the two parts of a continuously wound coil.) If now the portion AB is connected to a condenser, and the circuit formed is tuned to various standard frequencies, and the effective self-capacity found in the usual way, then the writer has shown* that the self-capacity of the part AB is given to a close approximation by

$$C_{AB} = C_1 + C_2\frac{M_0^2}{L_1^2} + C_{12}\frac{(L_1 - M_0)^2}{L_1^2} \qquad (9)$$

Similarly the self-capacity of the part AF is given by

$$C_{AF} = C_2 + C_1\frac{M_0^2}{L_2^2} + C_{12}\frac{(L_2 - M_0)^2}{L_2^2} \qquad (10)$$

while the self-capacity of the whole coil is given by

$$C_{BF} = C_{12} + C_1\frac{(L_1 - M_0)^2}{L_t^2} + C_2\frac{(L_2 - M_0)^2}{L_t^2} \qquad (11)$$

L_t being the total self-inductance

$$L_1 + L_2 - 2M_0.$$

These equations are illustrated by results obtained by the writer for a very large coil of total inductance 50 mH. wound in three parts which could be disconnected from one another. Taking the centre portion (12 mH.) and determining its self-capacity under different conditions, the following values were obtained :—

(*a*) With the two overhanging portions connected so that M was positive :
Self-capacity = 32 $\mu\mu$F.

(*b*) With the two overhanging portions connected so that M was negative.
Self-capacity = 170 $\mu\mu$F.

The large difference is evidently due to the change in the value of $\frac{(L_1 - M_0)^2}{L_1^2}$, when M_0 changes its sign.

These values of effective self-capacity are, of course, values obtained on the assumption that the inductances of the coils are unaffected by changes of frequency. The actual physical fact with which we are concerned is a change in the reactance of the coil system with change of frequency. In this paragraph the change is regarded as entirely due to a capacity shunting the coil system, the inductances remaining absolutely constant. Alternatively, we may regard the inductance as variable with frequency, and express the same changes as changes in inductance. This is done in a subsequent paragraph headed Self-inductance Equations.

Determination of the Component Capacities of Transformers.

Equations (9), (10) and (11) may be used to determine the component capacities C_1, C_2 and C_{12} of a system of coils of this nature, for example, of a transformer, for if the self-capacities C_{AB}, C_{AF}, C_{BF} can be determined and the true inductances L_1, L_2 and M_0 are measured, then substituting the results in equations (9), (10), and (11), we obtain three equations, which are sufficient to determine the three unknowns, C_1, C_2, C_{12}. This method was successfully used by the writer in determining the component capacities of the subdivided 50 mH. coil previously referred to. It could possibly be used for analysing the capacities in a L.F. intervalve transformer, though the conditions in this case are rather difficult, since the primary and secondary coils are usually of enormously different inductances, and the presence of the iron core makes the application of Fig. 2 to the system only possible under conditions which might not permit the necessary self-capacity measurements being made.

Self-inductance Equations.

The properties of the system as regards self-inductance have yet to be considered. Butterworth* showed that the effective self-inductance between the points AB (Fig. 2) is to a first approximation given by

---

* *Loc. cit.*

*Butterworth, *loc. cit.* A term given by Butterworth depending on the resistance has been omitted, since it is negligible in all practical cases.

$$L_{AB} = L_1 + \omega^2\{C_1L_1^2 + C_2M_0^2 + C_{12}(L_1 - M_0)^2\} \quad .. (12)$$

and, similarly,

$$L_{AF} = L_2 + \omega^2\{C_1M_0^2 + C_2L_2^2 + C_{12}(L_2 - M_0)^2\} \quad .. (13)$$

In a paper already referred to, the writer has also shown that the overall inductance L_{BF} is given (approximately) by

$$L_{BF}=L_1+L_2-2M_0+\omega^2\{C_1(L_1-M_0)^2 + C_2(L_2-M_0)^2+C_{12}(L_1+L_2-2M_0)^2\} \quad .. (14)$$

Equations (12) and (13) may be regarded as showing how the effective inductance of a portion of a coil which is tapped off is increased by the " dead-end " effect. Again, they show how the effective inductance of a transformer primary or secondary is increased by self-capacity in both the primary and secondary windings, and also by mutual capacity between them. In this connection it must be realised that the expressions are only approximate. They no longer hold when the frequency becomes so high that the coils are near their self-resonance points. Thus they will not hold for L.F. intervalve transformers except at the lower frequencies, since such transformers possess self-resonance points in the working range. More complete equations for such cases have been given by Dr. Dye in his well-known paper* on intervalve transformers. The present equations do bring out a point emphasised by Dr. Dye. *viz.*, that the effects of secondary self-capacity and mutual capacity are exactly similar, and the one may readily be expressed in terms of the other. With regard to the sign of M, the same convention as before is to be adopted, that is, M is taken as positive when the directions of winding of the two coils are such that the flux due to the two coils traverses the magnetic circuit in opposite directions when current is passed through the coils in series. It is evident from equations (12) and (13) that the effect of mutual capacity is minimised when this direction of winding is adopted, which explains why the properties of a transformer can be altered very considerably by altering the common point on the two windings or by reversing the secondary coil.

---

* D. W. Dye, *E.W. & W.E.*, September, 1924.

The Design and Distribution of Wireless Broadcasting Stations for a National Service.

Paper read by Capt. P. P. Eckersley, M.I.E.E., before the Wireless Section I.E.E., on 1st February, 1928.

ABSTRACT.

PART I.

HISTORICAL.

IN this introductory section the author briefly traces the history of the development of the B.B.C. stations. The establishment of the main and relay stations was regarded as bringing the urban population of Britain within reach of an uninterrupted service, while the long wave Daventry 5XX brought the percentage of the population living within the service area of a station up to 85 per cent. It is estimated that 50 per cent. of listeners rely upon 5XX, and that no other station is listened to in 90 per cent. of the rural areas.

Recently the "regional scheme" has been experimentally started by the high power medium-wave station at Daventry 5GB, giving programmes contrasted with those of the older long-wave station.

SERVICE AREA.

The "service area" of a station is regarded as an area around the station within which certain guarantees of service can be given. The author defines service areas in terms of field strength (millivolts per metre), definitions which, although arbitrary, have been accepted by the Technical Committee of the Union Internationale de Radiophonie.

Definitions.—Service areas are defined under four categories:—

(1) "Wipe Out" area, in which the field strength s over 30 mv/m.

(2) "A" service area, in which the field strength is over 10 mv/m. Service can be guaranteed even near the usual sources of electrical interference, trains, electric signs, etc.

(3) "B" service area, in which the field strength is over 5 mv/m. Crystal reception can be guaranteed with a good outdoor aerial.

(4) "C" service area, in which the field strength is greater than 2.5 mv/m. Listeners will be subject to interference from spark sets, trains, atmospherics, etc., but in time should be assured of an 80 per cent. service because it is hoped that some of these sources of interference will be eliminated at the source.

As fading may set in at 80 to 100 miles, the ideal would be to make a "B" service area have 100 miles radius.

Prediction of Service Area.—The extent of service area is difficult to predict, and is influenced by wavelength, type of ground around a station and the design of the transmitting aerial.

There is evidence to show that between the frequencies of 500 kc. and 1,500 kc. (600 to 200 m.) of the broadcast range there is considerable difference between the attenuation at the higher and lower frequencies. The curves of Fig. 1* illustrate the effect.

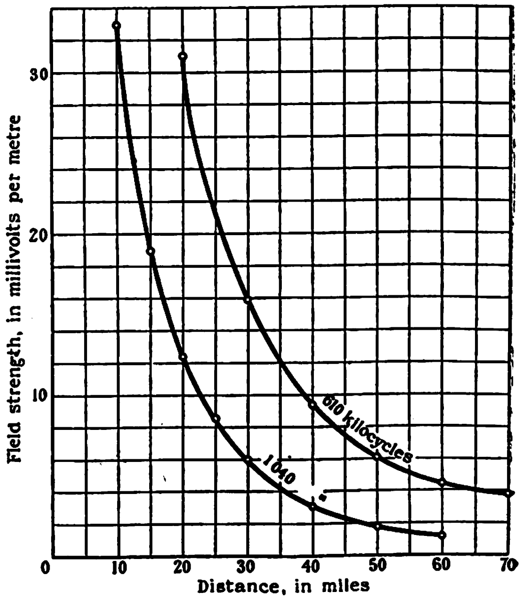


Fig. 1.

As regards the effect of the ground round the transmitter, the author refers to Mr. R. H. Barfield's recent contour map of the field strength round 2LO (see *E.W. & W.E.*, January, 1928), where trees were shown to add greatly to the attenuation, while he also quotes measurements made in Sweden in which the effect of forests is clearly shown.

In the design of the aerial, the object should be to radiate as much as possible horizontally and as little as possible in other directions, *i.e.*, low-angle radiation is to be preferred. The efficiency of the aerial should also be a maximum.

A vertical $\frac{1}{2}\lambda$ aerial is generally assumed to have the flattest vertical polar diagram at about 1,000 kc., but an aerial of this type for 500 metres would have to be 750 ft. high. A mast of about 300 ft.

---

* The author's original figure numbers are adhered to throughout this abstract.

is more practicable, and in this case it would be preferable to use a **T** aerial having a natural wavelength as nearly as possible twice that to be radiated. This would be obtained with a horizontal part of about 250 ft. Tests with a **T** aerial 250 ft. long on 110 ft. masts, and with a **T** aerial 600 ft. long on 500 ft. masts showed a mean field strength at 70 miles of 30 to 50 per cent. in favour of the higher masts. The half wavelength aerial produces larger interference at comparatively long ranges at night, due to the low-angle radiation causing a small angle of reflection from the Heaviside layer.

To increase the effective height of aerials it is convenient to separate the aerial system from the transmitting station buildings, and experiments on the use of feeders for this purpose at 5GB are described.

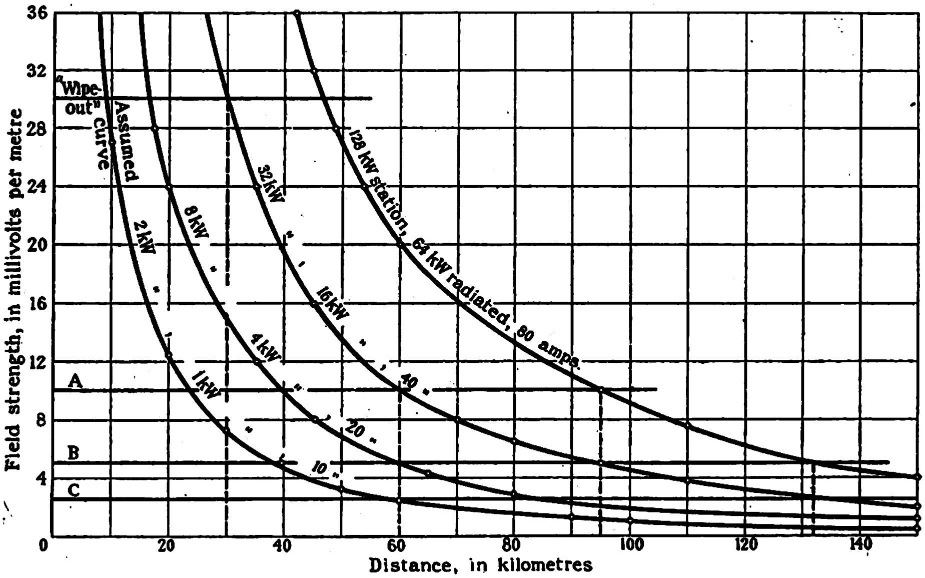


Fig. 2.

The effect of masts is also considered. The desirable polar curve of the radiating system may be distorted, and the effective height of the aerial reduced. The author concludes that it would appear best to arrange insulated masts as far from the aerial as possible, so as to minimise their effects both by eliminating resonance and strong induction.

The above factors introduce so many variables that a vast amount of data must be collected before the exact prediction of service area can be undertaken with any degree of confidence.

An approximate measure of the "A," "B" and "C" service areas against power used is shown in Fig. 2. The high-power station is more economical per unit of "B" service area than the low-power station, if each unit of area is assumed to give the same yield in licence revenue. Owing to non-uniformity of population, however, several low-power stations located in populous areas represent a more economical method of distribution than a single high-power station to cover the same area.

The author compares the advantages and disadvantages of using frequencies of about 200 kc. (*i.e.*, as of Daventry 5XX), and concludes that the ideal broadcasting system combines the use of medium-frequency and low-frequency distribution, and employs each according to its merits.

Limitation of Wavelength.

To avoid heterodyne interference, the only reliable principle is by separation of the fundamental frequencies between stations less than 3,000 miles apart. Since all frequencies up to 10 kc. require to be present in the modulation, the maximum difference between sidebands and fundamental must be ±10 kc. To prevent the sidebands heterodyning with another carrier, a separation of 20 kc. would be required, and to prevent sidebands heterodyning with sidebands 30 kc. separation would be called for.

This would leave an inadequate number of channels in Europe and would involve a large increase of power.

A separation of 10 kc. between fundamental frequencies allows for 101 stations in Europe within a frequency gamut of 1,500 and 500 kc. (200 to 600 m.). According to the Geneva plan, of the 100 available wavelengths, 84 were allotted for the exclusive use of the more important European stations, while the remaining 16 were to be shared between the surplus stations. Small power stations widely separated in geographical distance and working on the same wavelength would certainly produce little interference outside their service areas. If, additionally, they were working exactly or very nearly at the same frequency, their note of interference would be so low in pitch as to be almost inaudible.

The compromise thus arrived at provides a means to allow organisations to erect and maintain certain "local" stations without interference.

According to the Geneva plan, Britain has nine exclusive wavelengths, while 5XX makes ten channels in all available for British broadcasting.

The Provision of Alternative Programmes.

The author considers that the provision of alternative programmes more than doubles the value of a broadcasting service. To make selection between alternative programmes as simple as possible, the two transmissions must be of equal strength. Thus, if a listener lives in the "B" service area of one programme, he should also be in the "B" service area of the alternative. This is tantamount to saying that the two transmissions should be radiated from the same point.

In order to predict the effect upon existing receivers, a study was made of the use of twin wavelength stations producing roughly coincident field strengths over the service area of the stations.

The author's conclusions, amongst others, are (1) That if the frequency separation of two equal-strength transmissions is greater than 100 kc., the amount of further separation makes little difference to the extent of the interference between them. (2) That in most types of set met with it is impossible to produce sufficient selectivity to select between two equal-strength transmissions without some distortion of the frequency characteristic, and that many valve sets at present in use introduce distortion of this kind to some degree. (3) That the best and, in most cases, the only solution of the problem is to introduce some form of band filter. In its very simplest form this consists of a closed circuit in series with the aerial and tuned to the unwanted transmission.

After discussing methods of selectivity the author suggests that the next advance in receiver technique is to design the high-frequency side so that a square filter curve results, giving linearity of response over the desirable 10 kc. but selectivity by abrupt cut-off. He does not fear that the distortion of frequency characteristic to get reasonable selectivity (which occurs in the majority of present-day receivers) can be cited as a fundamental objection to the twin-wavelength transmitter system. The effects are slight and not irremediable.

Linking Together of Stations.

In this section, the author states that it is not necessary to discuss the many problems incident to landline linking. Experience has proved that it is perfectly feasible to rely upon the use of such connection, and that no serious loss of quality need be feared if the proper precautions are taken.

As regards the linking of national systems by wireless, he considers that short waves will prove most fruitful in yielding the required link. The problem is one of reception rather than transmission, and is largely bound up in the discovery of methods to equalise the intensity of the received signal.

In some experiments by Mr. G. M. Wright of the Marconi Company it was shown that reception conditions at two stations a mile apart were entirely different at the same moment. The strength might go up at one station and down at the other. This suggests that several receiving stations might combine to give a sensibly constant output, and the Marconi Company and the B.B.C. are stated to be collaborating in experiments to test the value of this theory in practice.

Continued experimental work upon a larger scale, using higher power, "beam" receivers, spaced aerials, suitable wavelengths, absolute constancy of transmitter frequency, etc., seems to be called for.

Single Wavelength Working.

The provision of alternative programmes would be simplified by several stations doing the same programme on the same wavelength, and in this section the author discusses some experiments that have been conducted working two stations in this manner.

Theoretically we should expect to find nodes and antinodes.

In the experiments, the Sheffield and Bradford stations (30 miles apart, 200 watts power) were both controlled in frequency by a 1,000-cycle source sent to each *via* landline and raised by valve frequency-multipliers. Radiating the same programme on the same wavelength, the quality was hopelessly distorted outside two or three miles of each transmitter. The trouble was attributed to phase changes in the line link, and the poor quality experienced was compared to night distortion observed when listening to distant stations.

It is stated, however, that experiments in America, Sweden and Germany, using high master-frequencies (about 20 kc.), have encouraged those responsible to put single wavelength operation into service. The author has initiated experiments in which the master drive is to be supplied from a low-frequency wireless station.

Distribution of Broadcasting Stations for a National Scheme.

In this final section of Part I, the author sums up the considerations given above, and discusses the proposed so-called regional scheme for broadcasting in Britain in which existing stations will be done away with and substituted by high-power twin-wavelength stations outside cities previously possessing single transmitters. The scheme assures to every listener an alternative programme, gives to the selective valve-set user a choice of as many programmes as may be occurring simultaneously—albeit some will fade and be interrupted—and makes the field strength over the country as uniform as it can possibly be under existing conditions.

PART II.

The Design of Broadcasting Transmitters.

The conditions for ideal performance of a broadcasting transmitter are:—

(*a*) The frequency/amplitude characteristic of the whole system shall be level. More exactly, for equal input of alternating voltage to the system, at any frequency between 30 to 10,000 cycles per second, there must be an equal modulation of the amplitude of the high-frequency aerial current.

(*b*) At any frequency between the limits stated, the modulation of the high-frequency aerial currents must be proportional (between the limits of practical full and minimum modulation) to the input voltage of modulation.

(*c*) The cost of maintenance in power charges should be taken seriously into account. Power economy for ideal performance should, in fact, be studied in comparing different types of transmitter.

(*d*) It should be possible to modulate the high-frequency aerial currents to the fullest possible extent without introducing distortion.

(*e*) Visual methods of detecting both the depth of modulation at any time, and any distortion, should be part of the equipment of every station.

(*f*) Great constancy of fundamental carrier-wave frequency is essential; in particular, the frequency of the carrier wave should be free from momentary "wobble" under conditions of modulation.

(*g*) As in every wireless station, freedom from harmonics in the emitted radiation is essential.

TYPES OF TRANSMITTER DISCUSSED.

The two types of transmitter here discussed employ choke-control of modulation, and are called "high-power" and "low-power" choke modulation transmitters respectively. The former system controls the aerial oscillations directly from a control circuit using a power equal to or greater than that employed in the last H.F. stage, while the "low-power" system modulates the high frequency at low power and uses the H.F. magnification to bring up the modulated high frequency to full power.

CHOKE MODULATION.

The author then considers the question of choke control, more especially as regards the high-power modulation system.

Condition (*a*).—The conventional diagram of choke control is given in Fig. 4, and its equivalent circuit is discussed in detail. It is pointed out that the choke has to have large impedance at low frequencies, and that the by-pass condenser is often of such value as to give a cut-off at the higher audio frequencies, *e.g.*, 6,000 cycles. Difficulties of iron saturation in the core increase with power, and the circuit of Fig. 6 (due to Capt. Round) is given as showing a method of neutralising the effect of D.C. in the choke. The transformer arrangement is of 1 : 1 ratio and the D.C. magnetisation of the core is made nil by a reversal of the winding direction or the direction of the D.C.

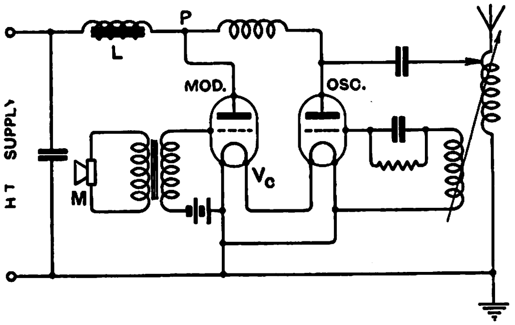


Fig. 4.

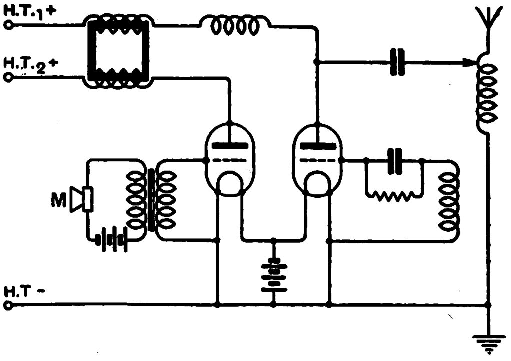


Fig. 6.

The high-frequency circuits, if of too low damping, cause a cut-off at the higher frequencies of modulation. By suitable aerial design this can be eliminated in the 1,500-500 kc. band, but is noticeable on the long wave of 5XX. A partial solution has been found by mistuning the aerial relative to the closed and drive circuits by 3 or 4 kc.

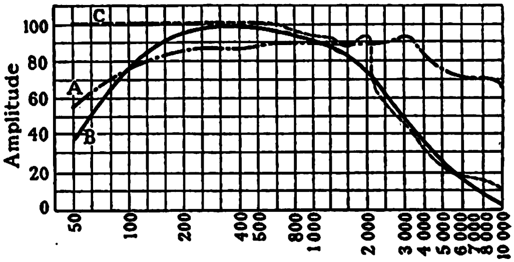


Fig. 7.

Inter-electric capacity may also add to distortion. In Fig. 8 the anode-grid capacity C_a of the final modulating valve will apply to the grid of V_m a voltage in partial antiphase to that from the coupling from V_s. "Neutrodyne" condensers used as a remedy have been found to introduce instability and it is concluded that this effect is best minimised by reducing the overall impedance of the L.F. amplifying system and to sacrifice high amplification per stage.

Distortion in the frequency/amplitude characteristic can often be traced, also, to a too small value of smoothing condenser, especially when V_s (Fig. 8) is supplied from the same source as V_m.

The frequency characteristics of 5XX and 2LO are shown in Figs. 7 and 9 respectively.

Condition (*b*).—In general a valve H.F. generator can be adjusted to give, between certain limits, a strict proportionality between H.T. voltage and aerial current. The study of the linearity of response is best made by a cathode ray oscillograph.

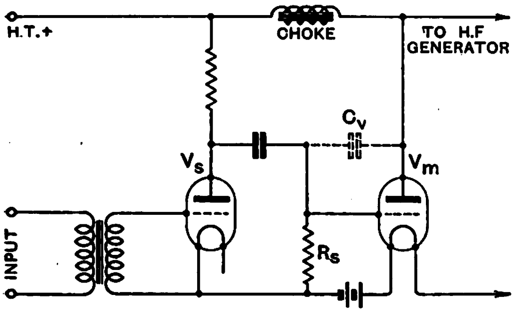


Fig. 8.

If the modulated H.F. component is applied to the *Y* axis and the input modulating voltage to the *X* axis, the result should be a triangular shape of pattern with the tip more and more cut off as modulation decreases (Fig. 10a).

In an experiment in which the H.F. voltage applied to the *Y* axis was compared at several values with the deflection of the cathode stream, it was found that there was a threshold voltage which, until passed, caused no deflection of the cathode stream (at such frequency as a million per second). This threshold voltage effect explains why, on occasions, the triangle picture (Fig. 10b) may extend its tip to an actual "crown," formed by the continuance of the intersecting sides. So long, however, as there is proportional modulation, the pattern must show straight sides. Fig. 10 (c and d) gives examples of how it may show non-linearity of response.

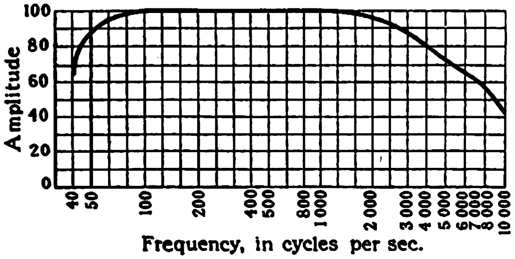


Fig. 9.

Grid current in choke modulation is a prevalent source of distortion. Present practice eliminates grid current as far as possible by adopting a considerable factor of safety and suitable grid bias.

It has been suggested to use a 100-kW transmitter at half or less power for normal modulation and to let greater modulation accrue when the music dictates. This, however, would introduce carrier wave "mush" in the receiver, and while "blasting" might be eliminated at the transmitter during a sudden *forte*, the receiver might not have the same factor of safety.

Curvature of valve characteristic may introduce distortion, but by choosing a considerable factor of safety in the modulator valves the effect in practice would seem negligible.

A slight distortion due to the drive circuit coupling directly to the aerial has been minimised by an anti-reaction coil, but a better method, used in the B.B.C. relay stations, is by a neutrodyne capacity connection shown as Fig. 15 in the author's paper.

Condition (*c*).—It is important to find a factor for every type of transmitter which gives the ratio between the total power absorbed from the output terminals of the power supply to the power in the aerial. The figures in Table 1 are based on the design of a 10-kW high-power modulation choke transmitter. What is defined as the power-conversion efficiency does not vary a great deal with different-powered stations:—

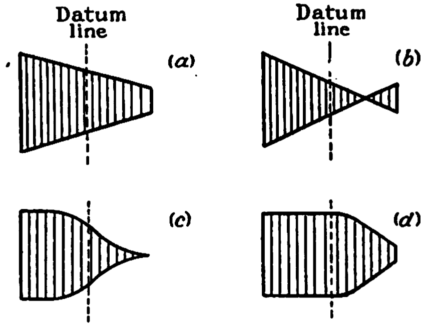


Fig. 10.

TABLE 1.

HIGH-POWER CHOKE-MODULATION TRANSMITTER.

Circuit.	Efficiency.	Power taken.
	per cent.	kW.
High-frequency magnifiers	70	14
Drive		2
Control valves H.T. ..		16.8 (14+20 per cent.)
Sub-control valves H.T. ..		1
Valve filaments (7 water-cooled valves; 20 volts, 50 amps.) ..		7
Miscellaneous valves ..		0.2
		41.0

$$\text{Power conversion efficiency } \frac{10}{41} = 24.5 \text{ per cent.}$$

Condition (*d*).—After discussing the voltage relations in Fig. 4 and its equivalent circuit, the author states that a very high degree of modulation can only be obtained in practice by using extra power in the control system. The scheme of Fig. 6 gives a greater efficiency of conversion because the voltage supply to the modulator anodes may be raised and the grid sweep increased by larger grid bias than when the H.T. supply was common, while this can also be made to balance the D.C. currents in the windings.

Condition (*e*).—Experience indicates that visual rather than aural indicators are essential to help the controller in his work. The control table, which is always remote from the transmitter, is equipped with two meters—one to indicate a maximum which must not be passed, the other to indicate a momentary volume. The former is arranged as follows: A sensitive milliammeter is connected in series with the anode of a small receiving valve, called the slide-back valve. The grid of this slide-back valve is backed off by a negative potential and is connected to the output terminals of the amplifier connected to the land line feeding the transmitter. It can be arranged that when the positive kick due to this output transformer is just so great as to give a flick of grid current (measured by a milliammeter in the grid circuit) at the transmitter, it also cancels the applied negative on the slide-back valve grid to such an amount that the anode milliammeter gives a flick also. Grid-current flick at the transmitter can, in fact, be synchronised with anode-current flick in the slide-back valve. "Volume," *i.e.*, R.M.S. or mean value of modulation, can be read by a hot-wire ammeter connected to the output valve of a conventional receiver through a step-down transformer, or by a milliammeter in series with the anode of a rectifying valve; these can be calibrated under steady sine-wave modulation against the voltage across the transmitter speech choke. The R.M.S. voltage of modulation at the actual transmitter in a choke-modulation system can be read by an electrostatic voltmeter or a straight-line valve rectifier and series milliammeter connected directly across the main choke of the transmitter. The latter system is better, as the scale is more open, the insulation easier and the movement more "dead-beat."

Condition (*f*).—In general, one may quite definitely state that the single "drive" with choke modulation is not sufficient to ensure the desired constancy of frequency. A load on the drive is caused by grid current in the high-frequency magnifier valves. This grid current varies with the anode voltage on the modulated valves. This throws a variable load on the drive circuit, and hence wave-wobble may result.

It is desirable, therefore, to separate the drive from the modulated valves by another stage. This double-drive circuit, or drive circuit using a "separator," is quite sufficient for all needs, since it not only ensures an excellent day-to-day and hour-to-hour constancy but is an insurance against wave-wobble under modulation. Tuning-fork and crystal drives give a greater constancy, but the author fails to see the need for them (pending single-wavelength working) if the simpler methods give stability and an accuracy sufficient for avoiding interference with other stations. It is essential that all stations shall be equipped with a very accurate wavemeter.

Condition (*g*).—To obtain reasonable efficiency harmonics must necessarily be produced, but these can be removed by suitable design of output circuit without serious losses at the fundamental frequency. The methods are well known and were discussed in Mr. E. H. Shaughnessy's paper on the Rugby Station.

Low-Power Choke-Modulation Transmitters.

Condition (*a*).—The low-power choke-modulation system can be made perfect as regards modulation provided no fresh difficulties occur in designing the H.F. amplifier. The cascade connection of tuned circuits might produce sideband cut-off, but this has been eliminated in practice by using suitable dampings and tight couplings.

Conditions (*b*) and (*c*).—These conditions are intimately related. The main power amplifier must be linear. If grid current is allowed a larger sweep is available, but this tends to produce non-linear characteristics unless certain precautions are taken. The most effective way is to make the impedance across the grid circuit so low that the voltage regulation is good, *i.e.*, so that the relation between the voltage applied to the input circuit and the voltage delivered to the grid is linear. Not only must the impedance be low at radio frequencies, but particularly at audio frequencies as currents at different frequencies are generated by the rectifying action of the grid. This is accomplished by the circuit of 5GB shown in Fig. 17, in which R_h is the shunt resistance and L_h is an air-cored choke.

The power-amplifier preceding the main magnifier is worked without grid currents.

It is instructive now to study the power-conversion efficiency based on a 10-kW transmitter and compare this with the factor for high-power modulation. This is shown in Table 2.

TABLE 2.

Circuit.	Efficiency.	Power taken.
	per cent.	kW.
Final power amplifier ..	32	31.3
1st power amplifier, 15 kW output	20	2.5
Modulation amplifier, 100 watts output	70	0.1
Modulators, etc.		0.4
Master oscillator		0.2
Separator		0.2
Power amplifier filaments		3.0
1st power amplifier filaments		1.0
Other filaments		0.4
		39.1

$$\text{Power conversion efficiency} = \frac{10}{39.1} = 25.5 \text{ per cent.}$$

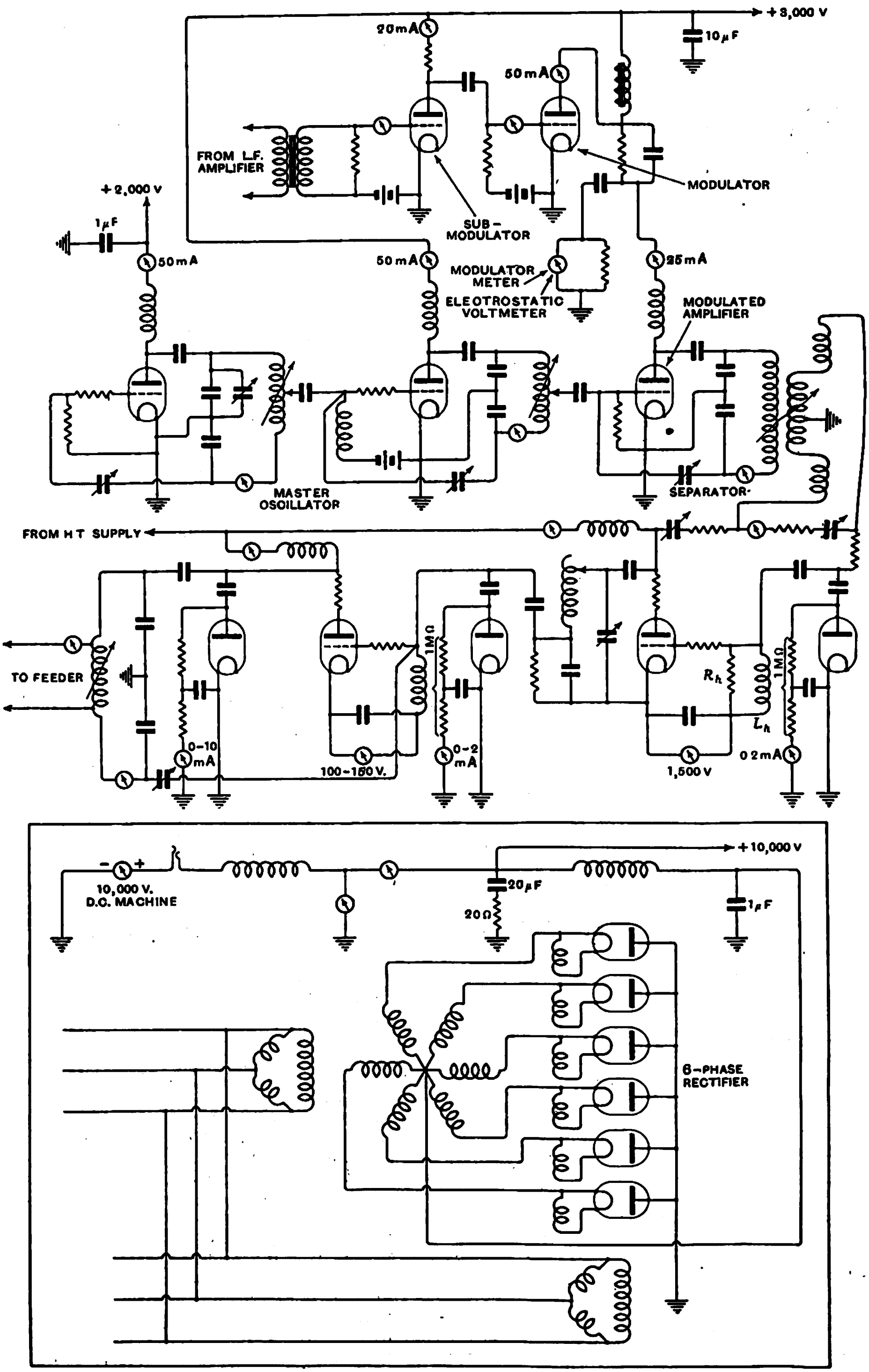


Fig. 17. *The circuit of the 5 G B (Daventry Experimental) Transmitter.*

Condition (*d*).—This is fulfilled more easily than in high-power modulation. Inefficiency is of less importance at low power and the modulator valves can be worked completely over the linear portion of their curves without grid current.

Condition (*e*).—The slide-back valve can no longer be calibrated against grid current in the modulator valve but against the peak voltage ratio of the final stage or the peak voltage modulation as read on a suitable modulation meter, *e.g.*, that of van der Pol and Posthumus.*

Condition (*f*).—This is easier than at high power. The master oscillator and separator are at low power less; screening is simple and efficient.

Condition (*g*).—The reduction of harmonics to a negligible amount is a matter of design of circuits, and very simple circuits of suitable and well-known design are quite effective in practice.

Fig. 18 shows the frequency/amplitude characteristics of the 5GB transmitter shown in Fig. 17.

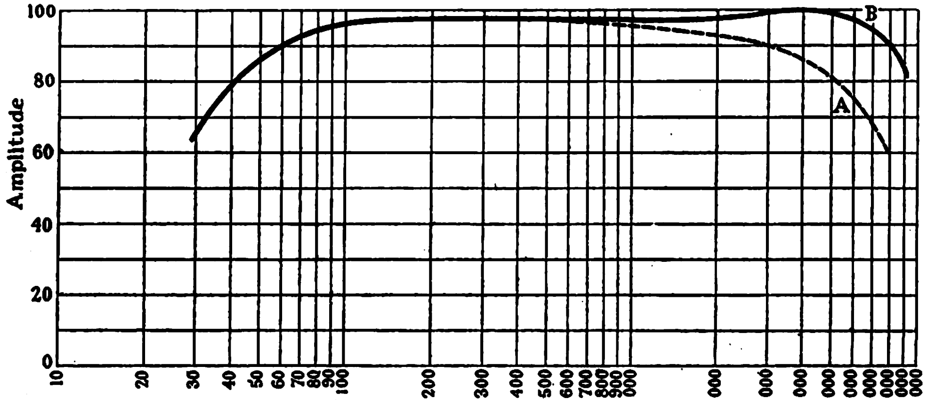


Fig. 18.

Curve *A* shows the sideband cut-off due to low resistance aerials; no steps have been taken to improve this effect because new aerials are being built which will remove it.

Comparison Between the Two Methods Described.

In summarising, the author believes that low-power modulation is superior to high-power modulation for the reasons:

(1) Better frequency characteristic.

(2) Greater factor of safety and greater stability.

(3) Requires to deal at high power with a frequency gamut of from 1.04 : 1 to 1.02 : 1 (using medium waves), while the high-power modulation system has to deal with a frequency gamut of 200 : 1 at high power.

(4) Efficiencies of power conversion are sensibly equal.

(5) Probably more flexible in changing from linear to non-linear modulation when this, by accident, may occur.

Valve Point Discharge.

Reference is made here to valve flash-over, which has been experienced at the broadcasting stations, but has presented less difficulty with high-power modulation than with low power.

Anode Power Supply.

In this final section, some interesting figures are given on the cost of anode supply power. A 50 kW station absorbs something like 300 kW, costing nearly £4,000 per annum for 3,000 hours' work per annum. The gain of efficiency in using a D.C. machine (83 per cent.) as compared to a rectifier system (60 per cent.) represents about £1,900 per annum. Even with the greater capital cost the use of D.C. generators represents a saving of £12,000 per annum on a scheme such as that proposed for Great Britain.

DISCUSSION.

In opening the very lengthy discussion which followed the reading of the paper, Mr. P. K. Turner referred to the immense value of the paper as a statement of policy. His first point of divergence was that he thought the author was pessimistic on the possibilities of the average set of to-day and to-morrow. In connection with the need of a frequency gamut of 30 to 10,000 cycles, he quoted a case where the loud-speaker was undoubtedly falling off at 50 cycles, but, while this was so, it was noticeable that the performance was improved when the range of the set preceding the speaker was extended from 50 to 30 cycles. As regards the suggestion of a band-pass filter with a sharp cut-off, he had used such a filter where the band, although fixed in width, was readily varied in its frequency position. The arrangement appeared full of promise. He asked whether it was practicable to transmit 30 to 10,000 cycles over land lines. As regards the depth of modulation at the transmitter, the detectors available could handle small modulation but could not deal with heavy modulation. "Control" of the level at the transmitter was a thing that could easily be overdone.

---

* *E.W. & W.E.*, 1927, Vol. 4, p. 140.

Mr. Mason thought the paper could not fail to give assistance to those concerned with the design of broadcasting transmitters. He was glad to see that the author was in favour of low-power modulation. His company had adopted this principle for transmitters of over 1 kW for some years. Capt. Eckersley hardly did justice to the low-power modulation system. He next turned to the matter of valve flash-over. There was less of this with rectifier supply, and the effect varied with the number of valves used in parallel. Could the author say if valves earlier in the cascade than the final power stage gave trouble? He disagreed with the author's figures about rectifier efficiency and gave 70-72 per cent. as a value. In the case of a D.C. generator, all the power supply was concentrated in one machine and provision against failure must involve complete duplication. On calculations on this basis he differed from the author on the respective costs of rectifiers and machine supply. As regards the frequency gamut, a transmitter had been designed in America for use in television with a flat frequency characteristic from 20 to 20,000 cycles.

Mr. A. J. Gill suggested that wooden masts were not an impossible solution of the effects of iron masts already experienced. Wooden masts at Rome and Horsea were examples. As regards the width of band necessary he showed a slide comparing the band *B* (of Fig. 7) with the band of 400-3,000 cycles used at Rugby on transatlantic telephony, and said that the Rugby arrangement gave excellent speech. He had, in fact, passed broadcast reception through a filter with a sharp cut-off at 3,000 cycles and could not tell the difference.

Mr. Minter said that while the author spoke of interference from spark sets, interference from a valve transmitter was well known in London, in an A service area, while he also quoted other cases of interference from valve sets. He was surprised that there was no measurement of the field round the transmitter. The Post Office had done so at Leafield. He thought the Rugby width of band might be quite applicable.

Mr. Ames asked for more information about Fig. 1. Had multiple-tuned aerials been tried? This method represented high efficiency at low cost. Was information available as regards the loss due to the effect of buildings as against that of transmission line feeders? In connection with masts, he suggested a metal mast on concrete and porcelain and the whole mast tuned by a coil. This could also be used as a multiple-tuned aerial.

Mr. R. A. Watson Watt asked for information as to the author's figures of the effect of the cathode ray oscillograph in examining modulation. What were the constants of the abscissæ against which the tube deflection was plotted? He inferred the figures as indicating a threshold of 8 to 12 volts.

Mr. E. B. Moullin spoke in favour of transmitting levels of field strength which permitted simple reception. He thought the field strength allowance indicated was liberal. At Cambridge the level was more of the order of ¾ mv/m. He would like more information on the effect of the aerials and upon the meaning to be drawn from the curves of Fig. 1.

Mr. Braendle spoke of the working of two stations on one wavelength, and asked how this affected sideband distortion. In the difficulties experienced, might not phase change occur in the transmission line conveying the modulation?

Mr. M. J. Scroggie referred to experiments in tuning when he had used a large aerial and a tap low down on the tuning inductance, an arrangement which gave considerable increase of the wanted signal strength. An aerial circuit even without reaction could be sufficiently sharp to cut off sidebands, and he quoted experimental figures which he has measured in this connection. In Fig. 17, 6-phase A.C. was shown. For what purpose was this used?

Dr. R. L. Smith-Rose referred to the matter of mast insulation, and the facilities provided at Rugby for either insulating or earthing. Neither seemed to make much difference. The distortion of polar diagram might, he suggested, be improved by a number of masts, say four. He questioned the soundness of rating a transmitter in terms of aerial power, since, without further specification of the radiation resistance, this gave no measure of the performance.

Capt. H. J. Round briefly referred to the comparison of ½λ and ¼λ aerials. As regards depth of modulation, the inability of the detector to handle heavy modulation, there was need for improvement in the rectifier at the receiver. He thought the author was rather hard on the high-power choke control. The decision as between the two systems must be made on which was the most hopeful in practice. In the case of low-power modulation there was more possibility of overloading the final H.F. amplifier than of passing the limits of modulation in the high-power system. Economy of power suggested a push-pull choke method.

Capt. Eckersley briefly replied to the discussion, more especially to some of the points raised by Messrs. Turner, Mason, Gill, and Round.

On the motion of the Chairman (Lt.-Col. A. G. Lee, O.B.E., M.C.), the author was cordially thanked for his paper.

Characteristic Curves of the Four-electrode Valve

By N. R. Hall, A.R.C.S.

SINCE the introduction of the four-electrode valve for the reduction of the anode voltage, some experiments have been made using higher anode voltages and various voltages on the grids, but the second grid so greatly increases the combination of voltages which can be applied to the various parts of the valve, that a set of characteristic curves is almost a necessity for useful experimental work.

The following curves have been drawn from a valve known as the U.C.5, which has two concentric spiral grids and a spiral anode, and takes 5 volts on the filament.

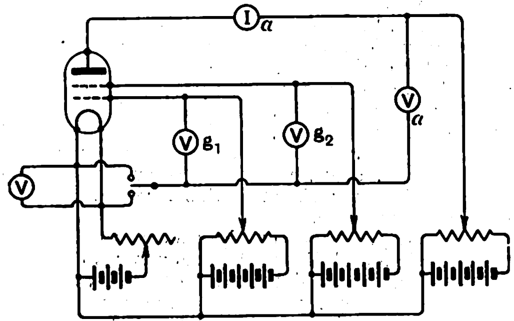
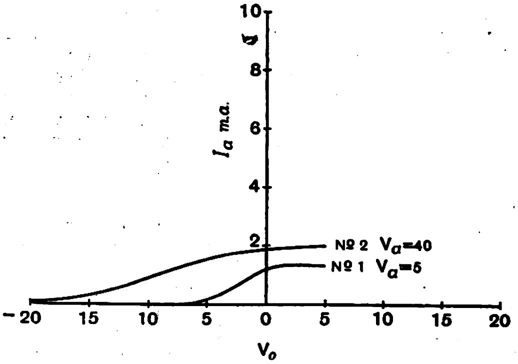


Fig. 1.

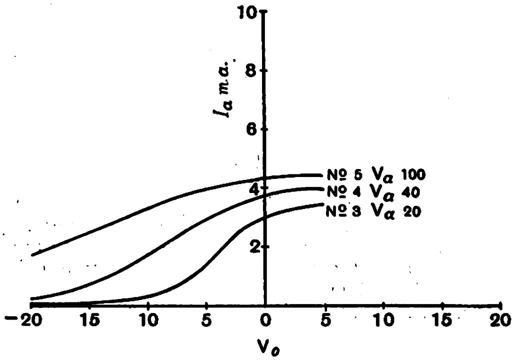
The characteristics of the three-electrode valve are generally given by a set of curves, connecting the anode current and grid voltage, the anode voltage being kept constant. This gives a separate curve for each value of the constant anode voltage. The amplification factor is obtained from these curves by finding the value of $\frac{\Delta V_a}{\Delta V_g}$ for a given rise of I_a, and limiting the values ΔV_a and ΔV_g to the straight parts of the curve. The grid resistance is given by the reciprocal of the slope of the curves, and the anode resistance is found by multiplying this by the amplification factor.

Another useful curve is that in which the anode voltage is plotted against the grid voltage for a constant value of the anode current. The slope of this curve at any point gives the amplification factor.



Curve 1.—*In these curves the inner grid is kept constant at 5 volts.*

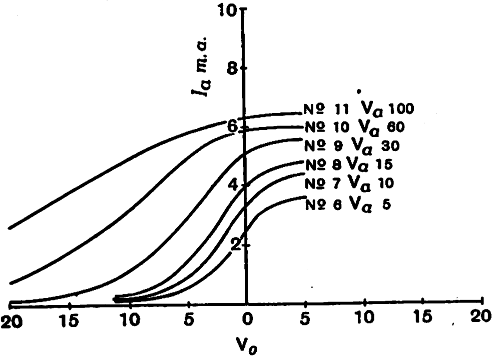
The four-electrode valve can be treated in the same way, but the curves must first be divided into two groups, in one of which the inner, and in the other the outer, grid is kept at constant potential. Having divided the curves into these preliminary groups, there will be a complete set of I_a, V_g curves for each value of the constant grid voltage. There will be two amplification factors, one for the outer grid and anode with the inner grid constant, and the other for the inner grid and anode with the outer grid constant.



Curve 2.—*Inner grid constant at 10 volts.*

The four-electrode valve is the same as the ordinary valve in appearance except that it has two concentric grids between the filament and the anode. The apparatus used for drawing the characteristics will therefore require another potentiometer to supply the extra grid. It is shown in Fig. 1.

The introduction of the second grid greatly increases the number of curves which have to be drawn to represent the behaviour of the valve; and some method will be useful in their arrangement. Taking the anode current as the dependent variable, there are three independent variables: the anode voltage and the two grid voltages.



Curve 3.—*Inner grid constant at 15 volts.*

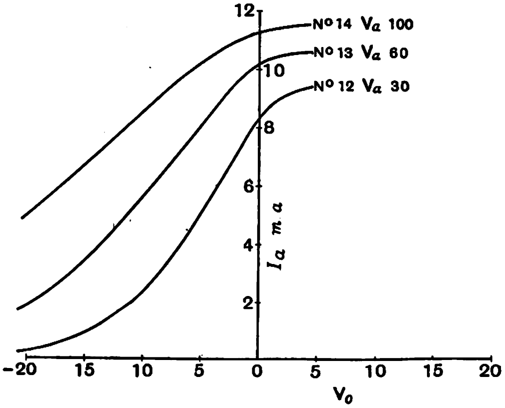
The curves have been divided into two groups, according to which grid is kept constant.

GROUP I—INNER GRID CONSTANT.

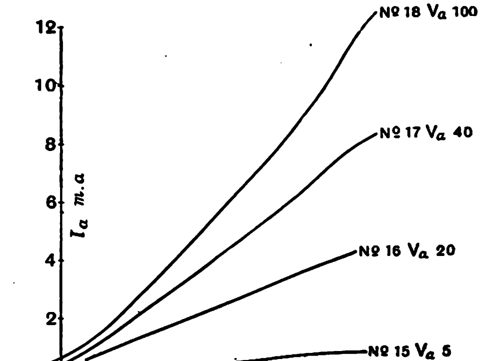
V_i	V_a	No.	R_a	Amp. factor.
5	5	1	10,000	2.8
	40	2	37,000	5.4
10	20	3	13,000	5.4
	40	4	22,000	5.4
	100	5	32,000	5.4
15	5	6	6,000	3.0
	10	7	6,400	3.7
	15	8	8,000	4.3
	30	9	10,500	4.5
	60	10	13,000	4.5
	100	11	20,000	4.5
25	30	12	6,200	3.8
	60	13	8,300	3.8
	100	14	10,000	3.8

GROUP II—OUTER GRID CONSTANT.

V_o	V_a	No.	R_a	Amp. factor.
0	5	15	—	—
	20	16	—	—
	40	17	13,400	4.3
	100	18	144,000	61.0
5	5	19	9,500	2.2
	10	20	17,000	4.8
	20	21	18,000	5.5
	40	22	144,000	63.0
	100	23	132,000	63.0



Curve 4.—*Inner grid constant at 25 volts.*



Curve 5.—*In these curves the outer grid is at zero potential.*

In the three-electrode valve we have :—

$$\text{Anode Resistance} = \left(\frac{dV_a}{dI_a}\right) V_g \text{ constant.}$$

$$\text{Grid Resistance} = \left(\frac{dV_g}{dI_a}\right) V_a \text{ constant.}$$

Voltage Amplification Factor

$$= \left(\frac{dV_a}{dV_g}\right)_{I_a} \text{constant.}$$

Using the same convention with the four-electrode valve :—

Anode Resistance $= \left(\frac{dV_a}{dI_a}\right)_{V_i \,\&\, V_0}$ constant.

Inner Grid Resistance

$$= \left(\frac{dV_1}{dI_a}\right)_{V_a \,\&\, V_0} \text{constant.}$$

Outer Grid Resistance

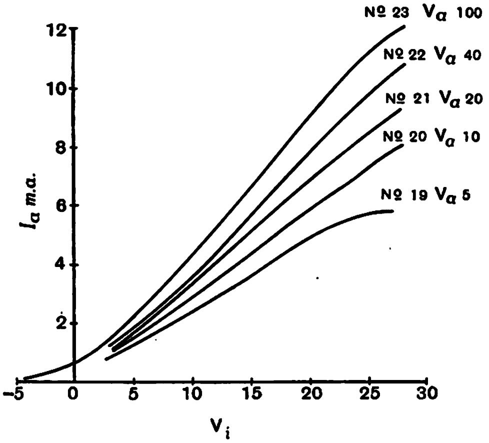
$$= \left(\frac{dV_0}{dI_a}\right)_{V_a \,\&\, V_i} \text{constant.}$$

Inner Grid Amplification Factor

$$= \left(\frac{dV_a}{dV_i}\right)_{I_a \,\&\, V_0} \text{constant.}$$

Outer Grid Amplification Factor

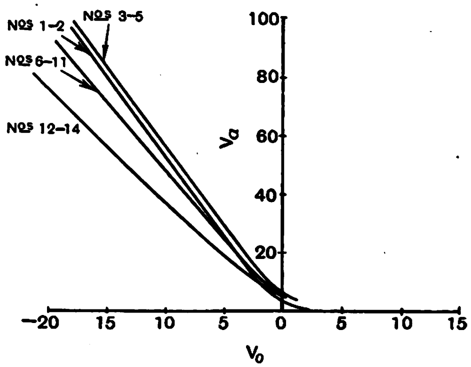
$$= \left(\frac{dV_a}{dV_0}\right)_{I_a \,\&\, V_i} \text{constant.}$$



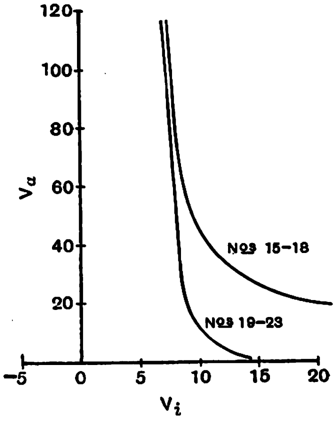
Curve 6.—*Outer grid constant at 5 volts.*

The first group of curves drawn with the inner grid constant are much the same as those of the three-electrode valve, except that amplification begins at a lower anode voltage. The first curve gives an amplification of 3 when the anode potential is only 5 volts, a voltage which can be supplied by the filament battery. The only other curves of this group which are remarkable are Nos. 6 and 7, which have the characteristic of a power valve with the very low voltage of 5 and 10 volts.

It is in the next group, in which the outer grid is constant, that the most interesting results are obtained. These curves differ from the three-electrode curves in that they are almost entirely on the positive side of the graph, and they are not at all parallel, resulting in an unequal amplification for different parts of the curve. The most interesting point is, however, that an amplification of over 60 is reached in Nos. 18, 22 and 23. This, it might be thought, is only due to the proximity of the inner grid to the filament, and could be obtained equally with an ordinary valve having a grid placed very near to the filament. But in No. 18 the outer grid is kept at zero potential, and an amplification of 60 is reached only when the anode potential is over 100 volts. No. 22, on the other hand, gives an amplification of 60 with only 40 volts on the anode, showing that the outer grid influences the results to a great extent. As might be expected, the outer grid current is considerable.



Curve 7.—*In these curves the inner grid is kept constant and the slope at any point given the "outer grid voltage amplification factor."*



Curve 8.—*In these curves the outer grid is kept constant and the slope at any point given the "inner grid voltage amplification factor."*

Calculations for Resistance Amplifiers.

By A. L. M. Sowerby, M.Sc.

THERE are occasions when the design of a resistance amplifier, even apart from the calculations of low-note and high-note loss, is not quite the simple matter that one expects it to be. Particularly is this the case when it is necessary to deal with large signal voltages, and the high anode potentials that they entail. The writer recently found himself confronted with the questions that arise in this way, and, having no experience to guide him, proceeded to do calculations instead. It is hoped that, despite several simplifying assumptions, these calculations may perhaps be of use to others who may find themselves in a similar position.

The kind of problem that arises can be most quickly seen from the diagram of Fig. 1. If, for example, T_2 is an L.S.5a valve with 80 volts of grid-bias, it follows that T_1 has to give a signal output V of peak voltage 80 volts without overloading. It is not easy to decide, at sight, whether any particular valve that one may have in mind will or will not give this output; it is still less easy to guess correctly the value of the anode resistance R that, with the available anode voltage E, will make the output V a maximum. Within certain limitations, these are all matters susceptible of easy calculation.

Let Fig. 2 represent the anode current-anode voltage characteristic of a valve (T_1 of Fig. 1). It is straight, or very nearly so, above a certain plate voltage, and over this range the resistance R_0 of the valve is constant, for it is equal to $\frac{dE_a}{dI_a}$. Producing the straight part backwards, it cuts the horizontal axis in P, at a distance E_0 from O. If we now look upon P as a "zero point" from which to reckon plate volts, and call $(E_a—E_0)$ the "effective plate voltage," *we can treat the valve as though it had a constant D.C. resistance equal to* R_0. But we must bear in mind, through all calculations based on this, that our conclusions will be untrue for all plate currents less than a certain minimum I_{min} at which the real curve begins to drop away from the straight line that we have arbitrarily substituted for it, and that in place of the *actual* plate volts E_a we must use for calculation the *effective* plate volts $(E_a—E_0)$.

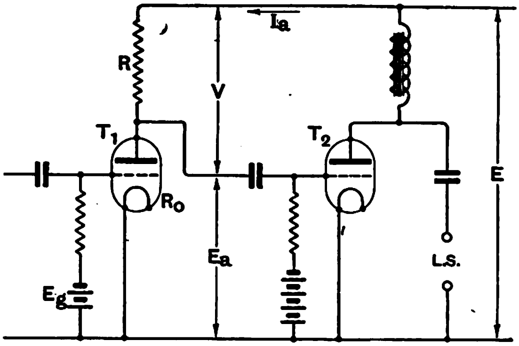


Fig. 1.

The method of determining E_0 experimentally is sufficiently obvious from Fig. 2.

If R_0=A.C. resistance of valve over straight portion of characteristic.
E =Voltage of anode current supply.
E_a=Voltage applied to anode of valve.
I_a =Anode current.

we can write :—

$$I_a = \frac{E_a - E_0 + \mu E_g}{R_0}.$$

If a resistance R is inserted in the plate circuit, then the plate current becomes :—

$$I_a = \frac{E - E_0 + \mu E_g}{R + R_0} \quad .. \quad .. \quad (1)$$

For distortionless amplification, the plate current of the valve can vary up to the maximum given by putting E_g=0 in the above equation; higher values than this imply that grid current flows. It can vary down to a minimum value I_{min}, at which point the characteristic begins to curve appreciably (Fig. 2). The total permissible swing of plate current is therefore given by the difference of these two currents, while the peak value attained is *half* this difference.

Max. change of I_a from steady value

$$= \tfrac{1}{2}\left\{\frac{E - E_0}{R + R_0} - I_{\min}\right\}.$$

This develops across R a varying voltage V of peak value

$$V = \tfrac{1}{2}R\left\{\frac{E - E_0}{R + R_0} - I_{\min}\right\} \text{ volts} \quad .. \quad (2)$$

and this is also the numerical value of the grid voltage that must be applied to the succeeding valve to enable it to deal with the signals without distortion.

This equation (2) enables us to calculate the maximum output that can be obtained from a valve of known constants, with a battery voltage E and an anode resistance R.

Our next concern must be to develop a formula for finding that value of R which makes V a maximum. This is done by differentiating the above expression for V with respect to R, and equating the result to zero:

$$\frac{R_0(E - E_0)}{(R+R_0)^2} - I_{\min} = 0,$$

whence

$$(R + R_0)^2 = \frac{R_0(E - E_0)}{I_{\min}} \quad .. \quad (3)$$

It will be appreciated that it makes for simplicity in use to leave the equation in this form rather than to attempt to find from it an expression for R; the latter is found from $(R+R_0)$ by subtraction.

We can also find the grid-bias required under working conditions; it must be half-way between the grid voltages corresponding to the two extreme values of plate current. It will be, therefore, E_g in the following modification of (1):

$$I_{\min} = \frac{E - E_0 + 2\mu E_g}{R + R_0}$$

whence

$$-E_g = \frac{1}{2\mu}\left\{E - E_0 - (R + R_0)I_{\min}\right\} \quad .. \quad (4)$$

Finally, we can find the working value of the plate current from (1); it is

$$I_a = \frac{E - E_0 + \mu E_g}{R + R_0} \quad .. \quad (5)$$

We may note also that:

$$E_a = E - I_aR \quad .. \quad .. \quad (6)$$

and that the overall amplification produced by the stage is:—

$$A = \frac{V}{E_g} \quad .. \quad .. \quad (7)$$

That is the last of the equations, but in order to make quite clear the way in which they are used, and the type of case to which they are applicable, one example will be given.

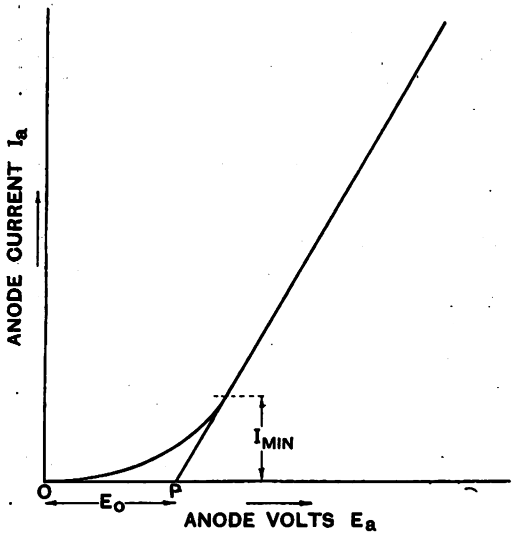


Fig. 2.

If T_2 of Fig. 1 has a grid-bias of 80 volts, and E is 300 volts, which will be the better valve to employ as T_1, a D.E.5 valve or a D.E.5b?

From the published curves of these valves, the following data are taken:—

	D.E.5b.	D.E.5.
μ	20	7
R_0	35,000	8,000 ohms.
E_0	50	26 volts.
$I_{\min}$	1	2 milliamps.

First we turn to equation (3), and find from it R. The values of $(R+R_0)$ come out at 105,000 and 33,000 ohms respectively for the two valves, so that the anode resistances to employ will be 70,000 or 25,000 ohms. Armed with these values, we turn to equation (2) and find V, the maximum output that can be obtained. For the D.E.5b valve this is found to be 49 volts only, so that it is quite clear that we cannot hope to feed T_2 from a D.E.5b, and that we must forgo the high amplification that this valve can offer us.

But the value of V found from (2) for the D.E.5 valve is 79 volts, which is quite near enough to the 80 volts required. This valve may, therefore, be incorporated in the amplifier, with its plate resistance of 25,000 ohms.

Equation (4) gives us the correct value of grid-bias to employ; it is 15 volts. Putting this value in equation (7) the actual amplification afforded by the stage is found to be 5.3 times. Finally, the working value of anode current, and the voltage that is applied to the plate of the valve itself, can be obtained from equations (5) and (6); they are respectively 5.2 milliamperes and 170 volts.

We have now satisfied ourselves that the valve in question is suitable for its purpose, and are in possession of the fullest working data for the valve as part of the amplifier. There remains nothing but to emphasise that the equations given are only valid when the anode voltage is sufficiently high, and the valve resistance sufficiently low, to ensure that the working value of the latter is not appreciably higher than the maker's rating. This will, in general, not be the case when valves of high resistance are used with high anode resistances, but if the value of E_a is found from equation (6) to be not less than about 100 volts, it may be concluded that the necessary conditions have not been violated.

Book Reviews.

THERMIONIC VACUUM TUBE CIRCUITS. By L. J. Peters, 244 pp. with 81 Figs. McGraw-Hill Publishing Co., London. Price 15s.

Starting with elementary thermionic theory including numerical examples, the author shows how the characteristic curves of two and three electrode valves arise. Passing on to elementary amplifier theory, he develops formula for power and voltage magnification, using resistance coupling. Conditions for maximum amplification are also determined. Reactance coupling is then treated for a single stage. Following this is a treatment of multi-stage amplifiers, the underlying mathematical theory being developed. The neutralisation of resistance by the aid of triodes and the analytical relationship concomitant with certain phenomena are treated in detail. Then follows the use of the triode as a generator of sustained oscillations; the usual expressions for oscillatory current and power are also given.

The reception of radio signals with its application to triode circuits receives attention. Formulæ are given for calculating the selectivity curve of a tuned circuit, and the problem of immunity from interference and atmospherics is broached.

After treating the problem of carrier wave modulation and showing analytically how the side bands originate, the process of rectification and the various frequencies associated therewith is sketched.

Finally, the theory and design of amplifiers is treated analytically, the input grid impedance being included. This latter is a feature we heartily welcome, since it is usually conspicuous by its absence. Unfortunately, the treatment of transformer coupling is marred by omitting leakage and the self- and mutual-capacities of the windings. As these factors control the performance of transformers at the higher audio frequencies, the analysis is only of value at the lower frequencies where the effect of inductance preponderates. It does, however, afford real interest, since it is at these frequencies that negative resistance effects (input impedance) play their shady part.

The book is mathematical throughout and ends with three appendices.

N. W. M.

PRACTICAL RADIO CONSTRUCTION AND REPAIRING. By Moyer and Wostrel. Pp. 319 and 157 Figs. McGraw-Hill. 10s.

This is an American book addressed to amateur constructors and repairers and to the radio dealer who has to test and repair sets. General workshop tools and methods are described, and elementary instructions given for testing valves and other accessories, instructions are given for the manufacture of a number of sets of various types, and also for making loud-speakers and battery eliminators. A chapter is devoted to what is called "trouble-shooting." A glossary of radio terms is given as an appendix, and we note that "M.U. = amplification constant." We suspect that this is someone's effort at "μ."

Although well adapted to the purpose for which it is written, we do not think that it will appeal so much to English amateurs, partly because of the difference of terminology, but mainly because the recommended components are often unknown in this country.

G. W. O. H.

AMERICAN GEOPHYSICAL UNION—ABSTRACT OF REPORTS AND PAPERS PRESENTED AT THE ANNUAL MEETING OF THE SECTION OF TERRESTRIAL MAGNETISM AND ELECTRICITY. April, 1927. 70 pp. Bureau of Standards, Washington, U.S.A.

This is a symposium of the correlation of various radio phenomena with solar and terrestrial magnetic and electrical activities. It contains 11 papers, including one by Pickard on radio-reception and solar activity, and another by Austin on the same subject. The concluding paper is a Summary of the others by Dr. Dellinger.

ELEMENTS OF RADIO COMMUNICATION. By Ellery W. Stone. Third Edition, revised and enlarged. Pp. 433, with 220 Figs. Chapman & Hall, Ltd. 10s. 6d.

This is an American book written by an officer of the U.S.A. Navy primarily for the use of naval students. It is of an elementary non-mathematical character and deals with the subject from an historical point of view; it goes fairly fully into descriptions of the various types of spark-gap, devotes considerable space to the Poulsen Arc, and never mentions the thermionic valve until one reaches page 331. Chapter 3 opens as follows: "Radio communication was made practical by Guglielmo Marconi, an Italian, who spent a great many years of his life in England and did most of his scientific work there. His greatest contribution to the art was the adoption of the grounded antenna, which is in use at the present time. Prior to Marconi, Hertz, a German, had employed ungrounded waves for radio purposes, but their range of transmission was limited," and then, after describing the plain aerial we are told: "However, this Marconi transmitter had one redeeming feature—it was a single circuit transmitter. That is to say, there was but one oscillating circuit. As such, it gave rise to waves of but one frequency or length, and was thus greatly superior to a later Marconi transmitter, which employed two oscillating circuits and thus radiated waves of double frequency." On page 331 we are told that "in 1883, or earlier, the American scientist Thomas A. Edison made known an interesting phenomenon which was observed in the manufacture of the *metal* filament electric lamp which he invented." This is a surprising thing to find in a third edition. The book is well illustrated and contains a lot of information expressed in simple language; it has evidently had a good sale in the States, but would not appeal so much to English readers.

G. W. O. H.

ELECTRIC RECTIFIERS AND VALVES. Translated from the German of Güntherschulze by N. A. de Bruyne. Pp. 212+ix. and 94 Figs. Chapman & Hall. 15s.

The name of Güntherschulze is well known to those who are acquainted with the German literature of the subject, and we welcome this translation of his book *Elektrische Gleichrichter und Ventile.* The translator points out in his preface that he has made a large number of alterations, the material for which was generally supplied by the German author; the translator has added paragraphs on the tantalum rectifier and the Moullin voltmeter. The word "valve" in the title is to be understood as applying to a piece of apparatus which lets the current pass one way only; the book is not concerned with three-electrode thermionic valves, and the Moullin voltmeter looks somewhat of an intruder. The subject is treated from the point of view of the physicist wishing to study the processes underlying the phenomena of rectification, the first half of the book being devoted to the physical theories and the second half to the technical applications of the various methods. Gas valves of the Tungar type, electrolytic valves, and mercury arc rectifiers both in glass and metal containers are all discussed fairly fully. Some mechanical types are described, but the translator regrets that he cannot give full details of Hartmann's mercury jet rectifier. This is unfortunate, as it was fully described and exhibited in operation at the British Association meetings in the first week of September, and the translator's preface is dated 25th August. We miss any reference to the copper-oxide rectifier which was on the market, and had been fully described in technical journals. These are minor matters, however, and the book contains a large amount of valuable information for those desirous of studying the physics of the subject, a mathematical discussion of the currents and powers in the electric circuits of polyphase rectifiers, and constructional details of various commercial types.

Sometimes things might be explained more fully, as, for example, on page 6, where it is stated that "with an elastic impact the energy given up by a colliding electron to a particle, which was stationary before the collision, is equal to 2 mm., where m=mass of electron and m_1=mass of atom, *i.e.*, the energy given up is independent of the velocity of the electron, which is not correct, and is not what is intended. We noticed this tendency to carelessness of wording in several places. In the preface the translator says, "Lest this book should fall into the hands of a purist, I will forestall his criticism by admitting that he will probably find much in it to offend his prejudices; but in a scientific book clearness is worth an occasional redundancy, and exact expression is more important than elegance of style." At the risk of being called a purist, I maintain that sentences such as the following: "A much greater voltage is necessary to send a given current strength through the gas *as* when free electrons are available," while certainly sacrificing elegance of style, add nothing to clearness. Exact expression and elegance of style are not so inconsistent as the translator believes.

G. W. O. H.

THE FOUR-ELECTRODE VALVE. By Fred Goddard. Pp. 104 with 64 Figs. Mills & Boon. Price 3s. 6d. net.

Only about 11 pages of this book are really concerned with the principles underlying the four-electrode valve. The last 70 pages are devoted to "some four-electrode valve circuits." We could find no mention of the screened valve, the only four-electrode valve about which most readers are concerned at the present time.

In the preface the author says that he is convinced that there is a need for something of this sort. We agree that there is room for a book on the four-electrode valve, but we should prefer something of a different sort.

G. W. O. H.

A Short Survey of Some Methods of Radio Signal Measurement.

By K. Sreenivasan, B.Sc.

The Paper is divided into the following sections :—

SECTION A.

1. INTRODUCTION. 2. STATEMENT OF THE PROBLEM. 3. THE EARLIEST EXPERIMENTS. 4. LATER EXPERIMENTS. 5. THE THERMIONIC VACUUM TUBE AND THE SUBSTITUTION METHOD.

SECTION B.

1. VALLAURI'S METHOD. 2. THE "ALDEBARAN" TESTS. 3. THE WESTERN ELECTRIC COY.'S METHOD. 4. BAÜMLER'S WORK. 5. AUSTIN'S APPARATUS. 6. THE MARCONI COY.'S METHOD. 7. THE N.P.L. METHOD.

Section A.

1. In the theory and practice of radio communication, the measurement of the field strength of received radio signals due to a distant transmitting station is gradually attaining an importance that can be hardly exaggerated. The phenomena attending radio communication are very numerous and complicated and not yet completely understood. In the design of apparatus to secure a reasonable degree of accuracy, compromise has to be made between a number of conflicting requirements. The variety of apparatus at present in use in various countries by different investigators only goes to show the degree of compromise that was considered necessary in the different cases.

2. The problem in its essentials is simplicity itself. Given a transmitting station T with a current I at the base of its aerial of height h, what is the intensity of the signal received at a receiving station R at a distance d from T? The ready answer to this question is: put up an aerial of known constants and measure the current in the aerial by some means and deduce therefrom the field strength. In principle, this is exactly what is done by every experimenter.

All the difficulties in the measurement arise from three causes: (*a*) the constants of the receiving aerial; (*b*) the method of measuring the current in the receiving aerial because of its extreme smallness; and (*c*) interference due to other stations and atmospheric disturbances. The current in the aerial is usually of the order of a few microamperes and the energy taken by it, of the order of a few billionths of a watt.

The number of investigators in this field is a fair indication of the complexity of the problem. Physicists, mathematicians and radio engineers all over the world have made and are still making great efforts towards the solution of this problem. Hertz set the ball rolling in his classical experiments, the starting point of all radio work and progress. From 1902 onwards, attempts have gone on with a gradual increase in the number of investigators and a rapid improvement in the apparatus used. Prominent among the names of those who have attacked the problem theoretically are Heaviside, Larmor, Eccles, G. N. Watson and H. M. Macdonald in the British Isles, Sommerfeld and van der Pohl in the European continent, G. W. Pierce, A. E. Kennelly, H. W. Nichols and J. C. Schelling in America, and Nagaoka in Japan. On the experimental side, there are L. W. Austin and Louis Cohen, Fuller, Englund, Bown and Friis in the United States, Vallauri in Italy, Lt. Guierre and René Mesny in France, Duddell and Taylor, Eccles, the Marconi Research Staff, and Hollingworth in England, and Max Reich and Baumler in Germany.

3. *The Earliest Experiments.*—If we consider the ideal Hertzian oscillator, consisting of two equal and opposite charges varying harmonically with time so far as their

magnitudes are concerned, then the intensity of the energy density decreases in proportion to the inverse of the square of the distance. This is from purely theoretical considerations.

In practice, however, the inverse square law is found to hold good when the distance does not exceed 50 miles. Beyond this limit, marked departures from this simple law are met with. Marconi was the first to find these differences in his investigations on the Atlantic Ocean in 1902. Chief of these were, first, that during the day reception was not possible at distances greater than about 800 miles from the transmitting station, while signals were easily readable at nearly 2,000 miles during the night; secondly, that signals were not of constant intensity either during the day or during the night.

Next in importance were the first systematic experiments of Dr. L. W. Austin and Dr. Louis Cohen on behalf of the American Navy during the five years, 1910 to 1915. The maximum distance covered during these experiments were 3,800 km. or 2,400 miles. As a result of their labours, these investigators evolved the well-known absorption formula, now generally called after them.

Let h_T be the effective height of the transmitting aerial,
λ, the wavelength,
d, the distance between the transmitting and receiving stations,
I_T, the current in the transmitting aerial,
h_R, the effective height of the receiving aerial,
and R, the resistance of the receiving aerial,

then the formula for the current in the receiving aerial is

$$I_R = \frac{120\pi h_R h_T I_T}{d\lambda R}.$$

This formula is based on the assumptions that (*a*) the surface of the earth is plane; (*b*) the ground is a perfect conductor, and (*c*) the atmosphere round the earth is a perfect di-electric. The formula itself is quite accurate for short distances and the assumptions are justified in such cases.

The absorption factor is of the form $e^{-kd\lambda^{-m}}$, e being the base of the natural logarithms. The experiments of Austin and Cohen gave for k and m the values 0.0015 and 0.5 respectively. This coefficient could not and did not fit into every value; it was a broad application to fit into average results for transmission over the sea, particularly for long waves.

Later, in 1914–15,* Fuller carried out measurements over longer ranges than Austin did. Between San Francisco and Honolulu, the distance is 3,800 km.; and the distance between Tuckerton and Honolulu is 8,000 km. For these distances, Fuller's coefficient—also of general application—was $e^{-0.0045d\lambda^{-1.5}}$.

These coefficients for absorption during transmission are not comprehensive. It would be well-nigh impossible to frame a formula which would take into account the time of the day, the season of the year, the nature of the medium between any two stations, clouds, thunderstorms and numerous other factors that may affect radio wave transmission. The formula should also include terms involving wavelength and distance. Even if such a formula could be framed, it would be so complicated and unwieldy that in arithmetical computation, for practical cases, its utility would really be small.

4. *Later Experiments.*—In England, Duddell and Taylor conducted the first accurate measurements of field strength by the direct measurement of the current in the receiving aerial with a sensitive galvanometer. The lower the value of the field strength, the more sensitive the galvanometer had to be. A limit was soon reached for the use of this method at about 60 miles from the transmitting station.

Following the direct method of Duddell and Taylor, came the famous experiments Drs. L. W. Austin and Louis Cohen carried on during the years 1909-1913. Fig. 1 shows the arrangement used.

At short distances from the transmitting station, the thermo-galvanometer was introduced direct in the aerial lead. At longer distances, the crystal and shunted telephone shown on the right-hand side had to be used. For still longer distances, the crystal and galvanometer circuit on the left hand, loosely coupled to the aerial circuit was necessary. The three methods were also used for checking against each other.

---

* Fuller, *Trans. A.I.E.E.*, Vol. 34, Part 1, p. 809.

With these arrangements, Austin and Cohen determined the field strength of the spark station, Brant Rock, over a distance of 1,000 miles on the sea, giving as the result of their work the well-known daylight formula which forms the basis of all later formulæ.

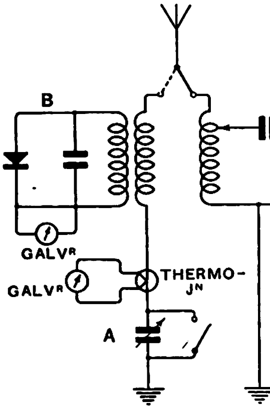


Fig. 1.—*Circuit used by Dr. L. W. Austin and L. Cohen,* 1909-1913. *The transmission was from Brant Rock and reception on two vessels at sea. The circuits A and B were for short and long ranges respectively.*

5. Meanwhile, the extremely valuable properties of the thermionic vacuum tube were gradually better understood and its value was in proportion appreciated. The flexibility in the use of this remarkable piece. of apparatus as an oscillation generator of almost all the desired ranges of frequency, a detector of spark or continuous waves, and an amplifier, rapidly made it indispensable in all radio frequency measurements, and specially so in field strength determinations. The old method of direct measurement came to be chiefly used for the determination of the effective height of aerials; and the modern "substitution" method, first suggested and used by Eccles, came to be exclusively used.

The principle underlying this method consists in equalising the E.M.F. induced by the incoming signal in the receiving aerial by a local easily regulatable E.M.F. The equalising or comparison is effected either by a telephone or a galvanometer.

Generally, the aerial used is either an antenna or a suitable closed aerial, the choice depending more or less upon circumstances. The E.M.F. induced is then magnified by one or other of the three well-known types of amplifier, the number of stages depending upon the strength of the signal. With the transformer or tuned circuit amplifier, elaborate and systematic shielding arrangements have to be undertaken.

After amplification and detection, and if necessary further low frequency amplification, the signal passes through a pair of telephones or a sensitive indicating instrument of the electrostatic or the electromagnetic type.

Next the deflections of the indicating instrument or the sound in the telephones are simulated by a locally controlled calibrated oscillation generator, generating at the correct frequency.

Due to personal equation in the telephonic method, the indicating instrument, *i.e.*, the galvanometric method is increasingly substituted in all modern accurate measurements. The galvanometer of the Einthoven type or the single string electrometer responds to the high speed signals of up-to-date stations; their deflections can be photographed continuously throughout the 24 hours to be kept as permanent records of almost minute to minute variations of signal strength.

There is one drawback in any signal measuring apparatus which may be safely put down as its weak spot; it is the single or multi-stage amplifier. If only it would work perfectly steadily with its characteristics unvaried for a reasonably long period, the amplifier would have extended usefulness as an instrument of great value. As it is, reproduction and repetition of results are impossible in the same manner as with the well-known types of measuring instruments. Its calibration in one form or other has become a necessity for every reading that is made.

The substitution method has rendered possible the measurement of extremely low values of field strength. Dr. L. W. Austin has measured the electric intensity of the high-power station Cavité to be 2μv/metre. Intensities of distant high-power stations can be anywhere between 10μv and 100μv per metre. Stations a few hundred miles away give intensities of the order of a few millivolts per metre.

Section B.

Vallauri's Method.—Almost the first to use the substitution method in the measurement of field strength is Prof. Vallauri. In the early part of 1919, when the radio station at Annapolis (Maryland, U.S.A.) carried on experimental transmission, Vallauri measured the strength of the incoming signals on behalf of the Italian Navy at his laboratory at Leghorn. His method is one of aural comparison, and accuracy to within 50 per cent. is claimed. Fig. 2 shows the diagram of connections used in these experiments.*

There are two large identical triangular loops at right angles to each other, one pointing towards the transmitting station, so that the other receives no signals at all. By throwing the switch L_1 L_2 to one side or the other, either of the loops can be connected to the antenna circuit, which is tuned to the particular wavelength required by a fixed condenser and a variometer V. This circuit is coupled inductively over a mutual inductance M_1 to a secondary circuit tuned by a fixed condenser and a variable air condenser. Across the latter is a six-stage resistance-coupled amplifier with the telephones at the output end. For beat reception the heterodyne oscillator G_1 is coupled to the secondary circuit over the mutual inductance M_3. The measuring circuit consists of a local oscillator G_2 coupled to the antenna circuit by the calibrated mutual inductance M_2.

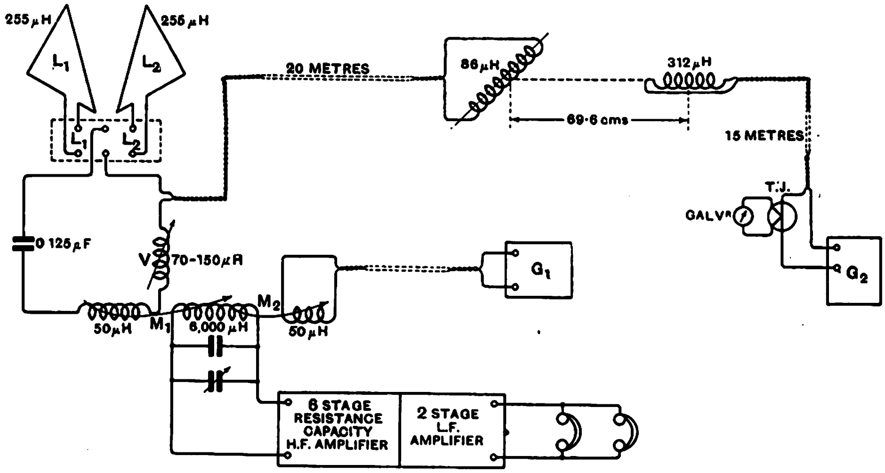


Fig. 2.—*Circuit arrangement employed by G. Vallauri in 1919. Observations were made at Leghorn, Italy, on the transmissions from Annapolis.*

The actual signal is received on the loop L_1 pointing to the transmitting station by throwing the switch to the side L_1. Generator G_1 is started and the signal is tuned by the variometer V; M_1 and M_3 are adjusted for the best and most convenient reception. G_2 is not in operation.

Next, the switch is thrown to L_2 on to the loop L_2; G_2 is started while all other adjustments are kept undisturbed and unaltered. The frequency of G_2 and the mutual inductance M_2 are so adjusted that the sound in the telephones due to this artificial signal is identical with that due to the actual signal. Rapid transfers of the switch from one loop to another ensure identity of the sound in the telephones. Knowing the dimensions of the loops, the current in the primary of the mutual inductance M_2, and the value of M_2, the field strength of the received signal is calculated.

In order to secure the highest possible accuracy the number of people listening in various telephones was six, and thus an average could be struck amongst the six observations.

2. *The "Aldebaran" Tests.* — Lieut. Guierre conducted, in 1919–1920, a series of tests on behalf of the French Navy on the sloop *S.S. Aldebaran.* The two main objects were to establish, if possible, the laws of wave propagation over an almost continental path and to investigate the field strength at

---

* *Proc. Inst. Radio Engs.*, Vol. 8, 1920, p. 286.

Tahiti,† the waves travelling almost completely over sea. The measurements were all relative to an arbitrary but invariable scale.‡

The arrangement of apparatus is shown in Fig. 3. The receiving aerial is loosely coupled to a two-stage amplifier with tuned grid coupling, followed by a detector with a telephone transformer and a pair of telephones shunted across by adjustable resistances R'' and R'''. A heterodyne, not shown in the figure, completes the arrangement for the reception of continuous waves. The whole of the receiving arrangement is well screened and earthed.

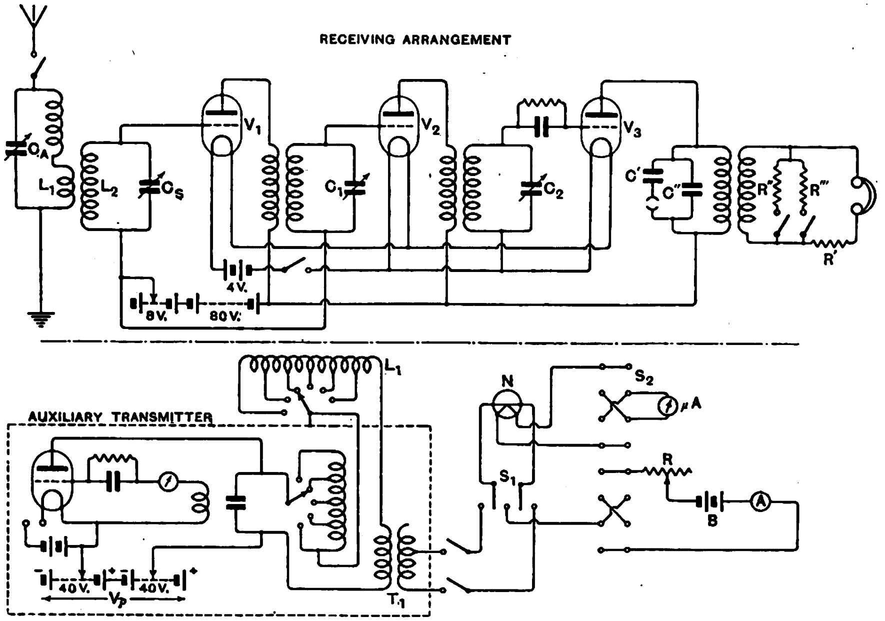


Fig. 3.—*Circuits used in the measurements undertaken by Lieut. Guierre, of the French Navy, on the S.S. "Aldebaran,"* 1919-1920. *The signals measured were those from Bordeaux.*

The auxiliary transmitter consists of an oscillating triode, the anode voltage of which can be varied within wide limits. The transmitter is also screened thoroughly with the exception of coil L_1, which forms the radiating part of the transmitter.

The two transmitters—the local and the distant—transmit alternately continuous dashes of 10 seconds' duration on exactly identical wavelengths, the alternation being controlled by chronographs. The method consists in equalising, both in pitch and in intensity, the signals due to the two transmitters by suitable adjustments of the shunt resistances across the telephones and the voltage of the auxiliary transmitter. This is claimed to be more accurate than measurement by extinction of sound. Lieut. Guierre says that personal errors due to the observer do not exceed 15 per cent.

The chief objection to this method is the elaborate organisation needed for an extended investigation into radio wave phenomena. Special signals mean for a commercial station, money, larger staff, more equipment and interference with the ordinary traffic. But the inestimable advantage of this method, specially in these days, lies in the fact that the synchronising arrangement removes the great problem of interference by the large number of high power stations not far from each other.

3. *The Western Electric Coy.'s Method.*§—To measure the strength of European radio

---

† Toulon and Tahiti form antipodes to each other.

‡ *Radio Review*, Vol. II, Dec. 1921, pp. 619-635.

§ 1. *Proc. Inst. Radio Engs.*, Vol. XI, No. 1, p. 26.
2. *Proc. Inst. Radio Engs.*, Vol. XI, No. 2, p. 115.

stations, Messrs. Englund, Bown & Friis developed measuring apparatus suitable either for aural or galvanometric reception.

The apparatus consists of a 6 ft. square loop aerial with 46 turns spaced ¼ in., a filter suited to the wavelength in question, followed by a complete amplification system with a telephone or continuous current galvanometer at the end. Calibration and comparison is effected by a local oscillator generating at the signal frequency, the output current of which passes through a specially designed attenuation box and feeds a one-ohm shunt across the coil aerial. Fig. 4 shows the arrangement. Thorough screening of the whole apparatus, by using copper lined boxes to house the various elements of the set, avoids mutual interference as well as the disturbances due to atmospherics, power and lighting lines, telephone circuits, etc.

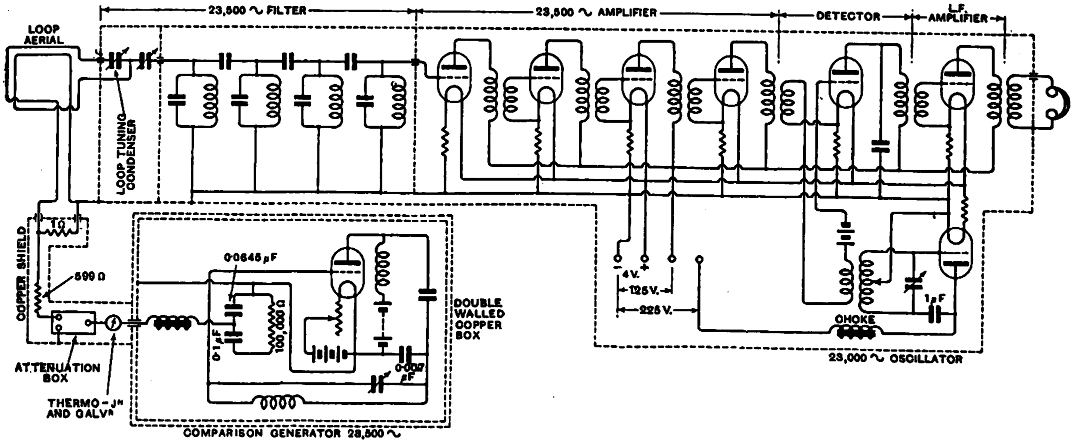


Fig. 4.—*Circuit used by Englund, Bown and Friis, of the Western Electric Coy., for measuring signal strength at Nauen, Marion, and New Brunswick,* 1922-1923.

Method of Operation.—The loop aerial is turned on to the maximum position of the signals; these are tuned, and pass through the filter and the amplification system. Statics permitting, a micro-ammeter is used. Otherwise, one has to use the telephones. Next, the local oscillator is turned on and its frequency adjusted to equality with the incoming signal. By means of a key the local oscillator is turned on and off during the spaces of the incoming signal, so that the two signals are heard alternately and give the same tone pitch, if of the same frequency.

The local signal is then adjusted by the artificial line to have the same loudness as the signal; the current in the line and its setting are noted. The field strength is given by

$$D = \frac{3 I_t F R_s \times 10^{18}}{2\pi f A N}$$

where

I_t = current in the line.
F = attenuation factor.
R_s = resistance of shunt across loop (one ohm).
f = frequency of signal.
A = area of loop in sq. cms.
N = number of turns in the loop.

The noteworthy points in this apparatus are:—

(*a*) The high degree of selectivity obtained by a rather elaborate filter.

(*b*) The method of getting small known radio frequency voltages by the artificial line or attenuation box.

(*c*) Injection of the small voltage into the aerial by a shunt resistance across its terminals.

(*To be concluded.*)

Dimensionality in Wireless Equations.

By W. A. Barclay, M.A.

THE subject of Dimensionality is one of the most interesting and important in modern physics, and one which is receiving much attention to-day. The various concepts dealt with, particularly in the sphere of electricity, are widely different in their nature, and their general co-ordination and interpretation is rapidly becoming a science in itself. It cannot yet be said, however, that any final body of doctrine exists in a realm where much is still left to conjecture. For example, the nature of the constants μ and k which relate the dimensions of electromagnetic and electrostatic quantities to the fundamental dimensions of length, time and mass is so far unknown, although the interpretation of the relation between the two is now classical. Closely allied to the subject of dimensionality is that of the units by means of which numerical magnitudes in the several dimensions are expressed. Electrical science in general has been peculiarly unfortunate in the different systems of units which have from time to time been proposed for practical working, and the new science of radio has had to extend the list still further with, *e.g.*, microamperes and picofarads. Such units are rendered necessary by reason of the extreme smallness of the H.F. currents dealt with. The clumsy system of wavelengths which was for so long in general use is now, happily, being superseded by that more convenient measure of frequency, the kilocycle.

It is not proposed to deal here with the absolute dimensions of the quantities which occur in wireless work. The most complete discussion of the subject known to the writer is that by Dr. N. R. Campbell in his monumental treatise *Physics, The Elements*, and to this work readers who may be interested are referred. The aim of the following note is the strictly utilitarian one of pointing out how the recognition of this concept of dimensionality may be of great service to the student and experimenter—as it has been to the writer—in checking the accuracy of equations to which they may be led in the course of theoretical work.

A physical equation is, of course, something more than a mere statement of numerical equality. The symbolism employed is designed to show the nature of the quantities whose equivalence is asserted, and in quantitative work the units in which the several magnitudes are expressed are, or should be, stated. In ordinary theory, however, it is usual to employ symbols which express a definite qualitative, in addition to a quantitative content, without any reference to units at all. Thus we speak of a resistance R, a capacity C, a reactance ωL or an impedance $\sqrt{R^2+\omega^2L^2}$, it being understood that the equations in which these symbols occur will be valid for any consistent system of units which may be selected for their numerical interpretation. The units must, of course, be self-consistent. In dealing with valve filament current, for example, we may use volts, amperes and ohms for our units; with grid currents, volts, microamps and megohms would be more appropriate. In both cases the equation $e=iR$ remains valid; that is to say, on substituting numerical values correct results would be obtained in either system. On the other hand, volts, microamps and ohms do not form a consistent system.

From the above considerations it is obvious that equations such as $e=iR$, represent a qualitative as well as a quantitative identity, a fact which may be otherwise expressed by saying that the dimensions of both sides of the equation must be similar. If, then, the left-hand side of an equation consists of the algebraical sum of quantities all of the same dimension, the R.H.S. must equally consist of a term or sum of terms each of that dimension. It is to be noted that if equations occur in which each side contains terms of different dimensions it can only mean that the sum total of all terms of any dimension on one side of the equation must equal the sum for that dimension on the other. In other words, we must equate separately to each other the individual dimensions from both sides of the equation, forming as many separate equations as there were different dimensions in the original equation. In a somewhat similar way the equations which express variation of current due to alternating E.M.F.s in a circuit when written in vector form are really the equivalent of two simple equations, in which the resistance and reactance components of the vector quantities are separately equated. The special meaning attaching to such equations should always be emphasised as a special technique is required to deal with them.

Apart from the vector equations referred to, the ordinary equations of wireless theory are generally uni-dimensional, and express the equivalence in dimension and magnitude between various physical quantities of the same kind. Thus, applying Kirchhoff's Laws to a current network, we are enabled to equate the sum of the P.D.s around the branches to the P.D. across the circuit. Here we have an equation between voltages, and every term in it is of the dimensions of a voltage. For any link in the circuit we have Ohm's Law, $i=e/R$. Here, both sides of the equation are of the dimensions of a current. We might also write it $e=iR$, where both sides are of voltage dimensions, or again $R=e/i$, which is an equation between resistances.

By thus multiplying the terms of an equation by suitable factors we may alter its dimensionality (having regard always to the laws of algebraical multiplication). It is thus possible to choose at will the particular dimensions with which we wish the equation to deal. This principle of selecting dimensions can be carried out within the equation itself. For instance, if the fraction A/B have the same dimensions as the term C in the equation

$$\frac{A}{B}=C$$

it is obvious that the intrinsic dimensions of A and B do not matter, and that we may alter the dimensionality of all the terms comprising the numerator A by suitable multiplication provided the same is done to all terms of the denominator B.

The general circuit equations of wireless are, of course, more complicated, but the same considerations hold throughout. We deal in fact with elaborate algebraical fractions and radicals which those unskilled in mathematics are apt to regard with distrustful aversion, while even a good algebraist must scan his working closely lest error should have crept in. The principle of dimensionality provides a certain test of error in such cases, though, unfortunately, it is no guarantee of correctness.

In these equations we deal with the absolute or numerical values of the impedances encountered, to the exclusion of their vectorial aspect. Such impedances may be expressed in ohms, equally with the resistances and reactances into which they may be resolved. Thus, the symbols R, ωL, $1/\omega C$ and Z may all be considered to have the same dimensions, viz., those of a resistance, and may be treated as resistances in the type of equations with which we are here dealing. For example, we may write the impedance of a resistive inductance to voltage impulses of frequency $\omega/2\pi$ as

$$Z=\sqrt{\omega^2L^2+R^2}\cdot$$

in which the dimensions of the R.H.S. are evidently those of the left. Again, for capacity, inductance and resistance in series, we may write the well-known formula

$$Z=\sqrt{\left(\omega L-\frac{1}{\omega C}\right)^2+R^2} \quad \ldots \quad (1)$$

This, of course, might be rewritten

$$Z^2=\left(\omega L-\frac{1}{\omega C}\right)^2+R^2 \quad \ldots \quad (2)$$

It will be observed that the terms comprising this equation have different dimensions from those of the preceding. Since, however, each of the terms of (2) has the same dimensions, those, namely, of a resistance squared, the equation is dimensionally correct. Had one of the terms differed in dimensions from the others, the inference would be that an error in working had occurred.

It is convenient in circuital equations to regard every term as the dimensional equivalent of a resistance, or of some power of a resistance (which need not necessarily be integral). In so doing, we need not concern ourselves at all with the physical interpretation of the various terms which occur in our working, such, for example, as the powers of resistances referred to. All that matters from the practical standpoint is that after the process of algebraical manipulation is completed, the final result shall be intelligible. Though any discussion of the philosophical considerations on which the procedure is based would take us too far afield for our present purpose, it is not to be thought that the process is in any way unscientific. Like the imaginary unit in algebra, "it works."

The ratio of two terms having the same dimensions is a pure number, and as such has no dimensions. For instance, such a quantity as $\omega L/R$ is a pure number. So also is ω^2LC, which is the ratio of an inductive to a capacitative reactance. For this reason, the oft-recurring expression $1-\omega^2LC$ is in order; should we at any time meet the expression $R-\omega^2LC$ in a similar context, we should at once suspect an error in working. Again, powers and roots of pure numbers cannot be other than pure numbers themselves, and thus the juxtaposition of such quantities as occur in the equation

$$\frac{Z^2}{R^2} = \frac{1}{\omega^2C^2R^2}\cdot(1-\omega^2LC)^2+1$$

which is another form of (2) is seen to be dimensionally correct. The factor $1/\omega^2C^2R^2$ is the square of a ratio of resistances. It, therefore, as well as the bracket term, is a pure number, and the equation is one in zero dimensions throughout. After a very little practice in looking at equations from this point of view it becomes possible to visualise at a glance the dimensionality of each term or component, and thus to "spot" a dimensional error at sight.

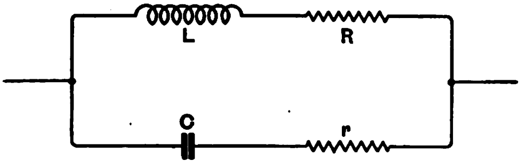


Fig. 1.

As another example, let us suppose that we have been led to the following value of L_0, the equivalent inductance of the circuit of Fig. 1 at the frequency $\omega/2\pi$,

$$L_0 = \frac{L(1-\omega^2LC)-\omega C(R^2-r^2\omega^2LC)}{(1-\omega^2LC)^2+\omega^2C^2(R+r)^2} \qquad (3)$$

As mentioned above, it is usually convenient to work as far as possible with quantities of the dimensions of some power of a resistance. We therefore multiply both sides by ω, thus,

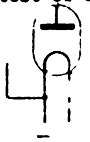
$$\omega L_0 = \frac{\omega L(1-\omega^2LC)-\omega^2C(R^2-r^2\omega^2LC)}{(1-\omega^2LC)^2+\omega^2C^2(R+r)^2} \qquad (4)$$

$$= \frac{\alpha-\beta}{\gamma+\delta} \text{ (say).}$$

The L.H.S. is then of the dimensions of a resistance. Now, the quantities γ and δ of the denominator are both of zero dimensions. From this it follows that both the terms α and β of the numerator must be of the nature of resistances in order that the equation may be dimensionally satisfied. The first term, α, is the product of a dimensional resistance, ωL, with a pure number, and so passes the test. The second term, β, consists of the expression $\omega^2C(R^2-r^2\omega^2LC)$. Now we have seen the combination ω^2LC to be of zero dimensions. The bracket factor is thus of the dimensions R^2. Multiplied by ωC, the reciprocal of a resistance, it would be reduced to the single power of resistance necessary for dimensional equality. There occurs, however, an extra factor ω, the presence of which destroys the necessary qualitative similarity, and indicates the presence of an error in the previous working. As a matter of fact, of course, the ω is superfluous, and equation (3) should be written

$$L_0 = \frac{L(1-\omega^2LC)-C(R^2-r^2\omega^2LC)}{(1-\omega^2LC)^2+\omega^2C^2(R+r)^2}$$

Although the selection of a resistance for the fundamental unit in the above exposition is entirely arbitrary, its use, nevertheless, will be found a matter of practical expediency. Once the significance of the various combinations of symbols in relation to the resistance unit is appreciated, the principle affords a useful means of checking equations by mere inspection. It is well, however, to repeat the warning that although *necessary*, it is not in itself a *sufficient* test of correctness.



The Frenotron Valve—A Vienna Novelty*

THE ordinary back-coupled detecting valve has two disadvantages: first, to obtain the greatest sensitiveness the back-coupling has to be increased until the oscillation point is nearly reached, and secondly, the rectified current is not proportional to the voltage applied to the grid, but to its square, causing insensitiveness to weak signals and distortion of loud ones. To obtain stable adjustment in the neighbourhood of the oscillation point, Dr. Pollak-Rudin connects a variable shunt resistance across the condenser of the tuned grid circuit. This shunt should have a high resistance when the signals are weak and a decreasing resistance as the signals increase in strength or as the voltage across the condenser terminals increases. In Fig. 1 this shunt is shown as a crystal detector, and in Fig. 2 as a diode, the action of which can be adjusted by means of the potential divider *P*. To avoid the necessity of adjustment which would make these methods somewhat troublesome, the shunt diode has been incorporated in the valve as shown in Fig. 3, when the filament is seen to extend beyond the normal grid and anode and act as a cathode to the special anode *H*. The connections for the valve are shown in Fig. 4.

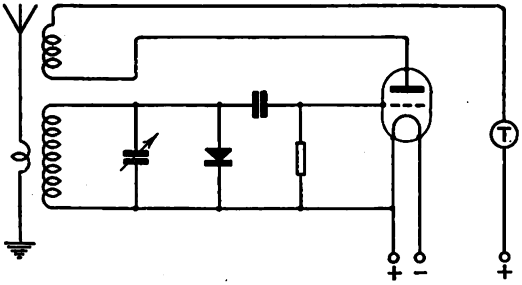


Fig. 1.—*The shunt shown as a crystal detector.*

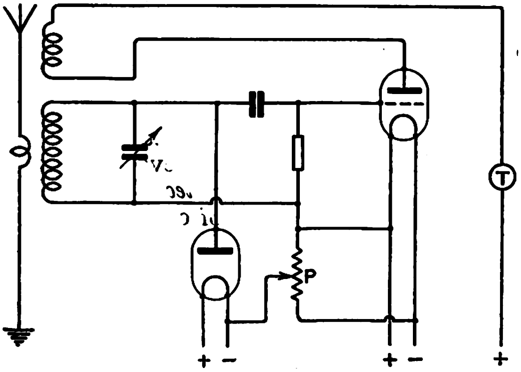


Fig. 2.—*The shunt as a 2-electrode valve.*

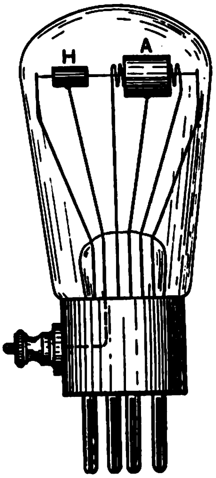


Fig. 3.

Although devised primarily as a stabilising device, the new valve has great advantages from the fact that the rectified current is no longer proportional to the square of the electromotive force induced in the grid circuit, but is approximately directly proportional to it. This proportionality leads to a decrease in distortion. This is discussed mathematically in the original article.

G. W. O. H.

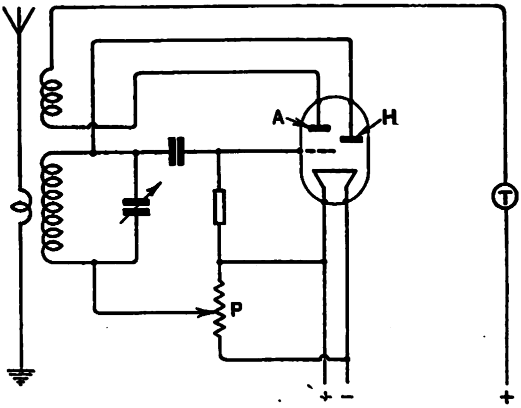


Fig. 4.—*Connections for the Frenotron valve.*

---

* From an article in "Elektrotechnik and Maschinenbau," Vienna, 13th November, 1927.

Some Practical Applications of Quartz Resonators.

Paper read by Messrs. G. W. A. Cobbold, M.A., and A. E. Underdown, before the Wireless Section, Institution of Electrical Engineers, on 7th March, 1928.

ABSTRACT.

THE paper deals with different applications of the quartz crystal, the latter half of the paper more especially dealing with certain applications developed by the authors at the Signals Experimental Establishment, Woolwich.

INTRODUCTION.

In a lengthy introductory section, the authors refer to early work on the subject by Cady, G. W. Pierce, E. Giebe, D. W. Dye, and others. The use of the crystal as a frequency standard and frequency stabiliser is discussed, these being the applications dealt with in the paper.

When a valve and a crystal resonator are associated in such a way as to maintain oscillation, the frequency of which is controlled by the resonator, the complete circuit is generally referred to as a quartz "oscillator." Although other circuits using the quartz crystal have proved valuable, it appears to the authors that for practical applications the quartz oscillator is likely to dominate the field of usefulness.

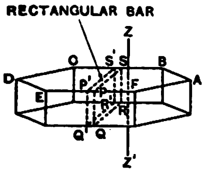


Fig. 1.

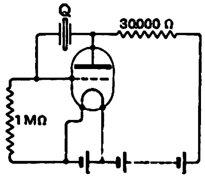


Fig. 4.

Fig. 1* is given as illustrating the manner in which a rectangular bar is normally cut from a block of natural quartz. The surface *ABCDEF* is at right angles to the optical axis ZZ^1. The three electrical axes are *AD, BE* and *CF*, and in the case illustrated the length of the bar, *PS*, is at right angles to the electrical axis *AD*. This perpendicularity to one of the electrical axes is not essential, however.

Notes are also given in the paper on cutting, grinding and mounting the crystals, reference being made to Hinderlich's paper on this subject.† When the crystal is used as an interference resonator a very appreciable air gap between crystal and electrode is generally provided in practice, but in the case of crystals used for oscillators the air gap is usually either extremely small or entirely absent.

A brief discussion is also given of the relationship between dimensions and fundamental frequencies, and of the equivalent electrical network of a crystal system.

In drawing a comparison between the quartz oscillator and other frequency standards, the usual standard method of an elinvar fork and multivibrator is considered to be preferable as national or international standards of the very highest order, but the authors consider that there is a great use for quartz resonators as secondary standards, especially for short waves.

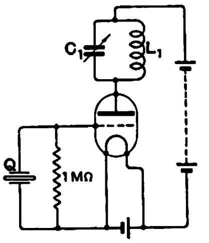


Fig. 5.

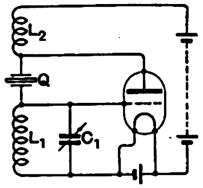


Fig. 6.

Practical applications already described in the technical press are then reviewed.

EXPERIMENTAL WORK.

In this section the authors deal with various experiments carried out by them since 1925. These have chiefly been in the development of quartz oscillators.

In the experiments crystals of the "bar" type were employed, measuring approximately 18.5 mm. long, 5 mm. wide, and 1.5 mm. thick, the width being parallel to the optical axis and the length and thickness respectively perpendicular and parallel to one of the electrical axes. Army pattern valves A.R.3 (L.T. 2v., H.T. 48v.), proved quite satisfactory in use.

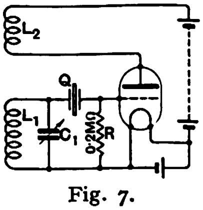


Fig. 7.

The circuits of Figs. 4, 5 and 6 were first tested, the last giving best results. The reaction circuit of Fig. 7 led to the final circuit of Fig. 8, the values shown being for a crystal of natural frequency 144.5 kc. (2,075 m.), the natural frequencies of all three coils being appreciably above that of the crystal.

---

* The author's original figure numbers are adhered to throughout this abstract.

† *E.W. & W.E.*, 1927, Vol. 4, p. 29.

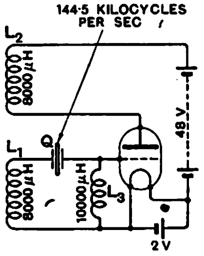


Fig. 8.

In order to obtain measurements of very small changes in the air gap, a crystal holder with a micrometer adjustment of gap was made, as shown in Fig. 9.

A series of tests was carried out to ascertain how the controlled frequency varied in accordance with known changes in the constants of the circuits, changes of air gap, temperature, etc.

The following results may be summarised:

(1) The results of measurement of the air-gap show the relative importance of the frequency change due to slight changes in a small gap of about 0.05 mm. in comparison with the effect of similar changes in a wide gap of about 1 mm.

(2) An increase of capacity of 54 μμF across the coils produced a decrease in frequency of 7 cycles in 144.5 kc., approximately 1 part in 20,000.

(3) For a 37 per cent. increase in inductance of *L1* or *L2* or a 33 per cent. increase in *L3*, a change of only 1 cycle in 144.5 kc. was observed.

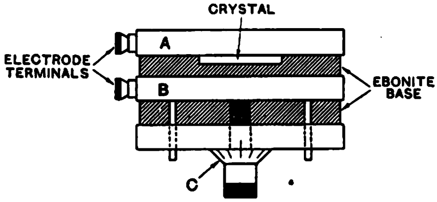


Fig. 9.

(4) 40 per cent. change of H.T. changed the frequency 1 part in 50,000; 10 per cent. decrease of L.T. caused a decrease of 1 cycle in 144.5 kc.

(5) Between temperatures of 55° and 125° F., results showed a temperature coefficient of − 4 per million per degree F.

(6) Change of valve for another of the same type, but of different make, never gave more than 2 cycles change in 144.5 kc.

(7) A variable condenser across *L1* gave a range of circuit tuning—in the absence of the crystal—of from 190 to 100 kc. Controlled oscillations of approximately 144.5 kc. were obtained for all values of the circuit frequency from 190 down to 145 kc. At this point they ceased and were not obtainable at any frequency below that value.

Experiments are also described using six crystals between two common electrodes, the crystals having wavelengths of 300, 320, 340, 360, 380 and 400 m., and being each brought into operation by appropriate inductance tappings.

Circuits for the frequency control for a small transmitter are also shown.

The frequency measurements in these experiments were made against a multivibrator wavemeter (N.P.L. design) with a valve-driven elinvar fork of 1,000 cycles. The apparatus includes a multivibrator of 1 kc., and a high-frequency multivibrator which can be set to 19, 20 or 21 kc. From this can be obtained oscillations at any frequency between 100 and 1,200 kc., which is a multiple of either 19, 20 or 21 kc.

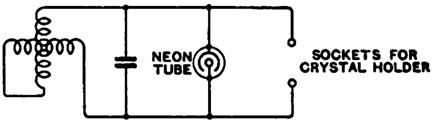


Fig. 15.

USE OF QUARTZ CRYSTALS WITH A NEON-TUBE WAVEMETER.

The authors then turn to applications of the quartz crystal on which they have been engaged. These are chiefly in connection with wavemeters.

The first case is the use of a crystal as resonance indicator using the circuit of Fig. 15. With a powerful source of oscillations a resonance curve such as that of Fig. 16 is obtained. The neon lamp glows over the region *AEPRD*, but the insertion of the crystal causes the crevasse *PQR* due to the absorption of energy by the crystal. In practice *BC* represents a very minute change of frequency, about 1 in 10,000. *ON* and *OM* need not be equal, although they should not differ by a great amount and the intersection of the crevasse

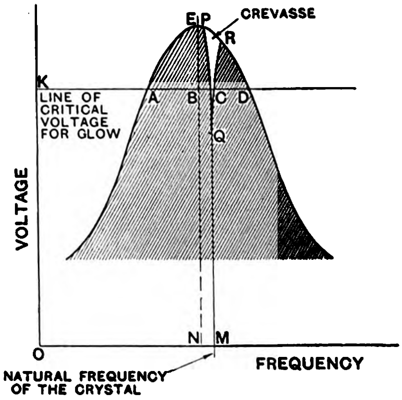


Fig. 16.

with the line *KAD* should not occur too close to either *A* or *D*.

This arrangement may be used to check the calibration of a wavemeter at as many points as there are crystals provided, and the authors illustrate a holder in which four crystals are permanently enclosed to provide such points.

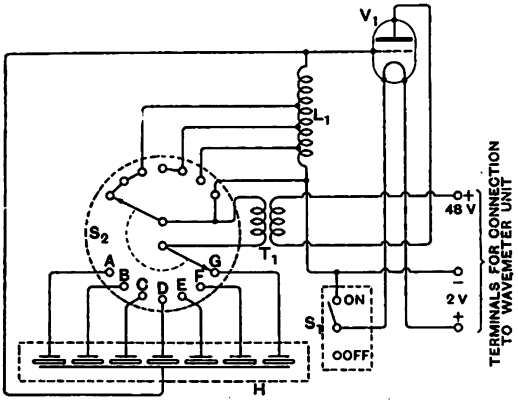


Fig. 18.

Practical notes are also given on the use of this method.

USE OF ! QUARTZ CRYSTALS AS REFERENCE STANDARDS IN CONJUNCTION WITH A SUB-STANDARD WAVEMETER.

Fig. 18 illustrates a quartz oscillator using seven quartz bars in a common mounting, to be used in conjunction with a sub-standard wavemeter covering the range of 100 to 4,800 m. The wavemeter is an oscillating valve circuit with telephones so that its oscillations may be heard beating with those of the quartz oscillator. The seven crystals have the following wavelengths corresponding to their longitudinal modes of vibration: *A* 1,800 m., *B* 1,600 m., *C* 1,400 m., *D* 1,300 m., *E* 1,200 m., *F* 1,100 m., *G* 1,000 m. The wavelengths have been accurately measured, and a calibration chart is provided with the instrument, giving the fundamental wavelengths and all the harmonic derivatives between 100 and 4,800 m. The quartz oscillator unit is normally connected up to the wavemeter with which it is used, the working voltages being supplied to the three terminals by means of connecting straps from the wavemeter. The instrument may, however, be used separately, when batteries should be directly connected to the terminals.

USE OF A QUARTZ OSCILLATOR IN A WAVEMETER GIVING A SERIES OF WAVELENGTHS THAT ARE ALL MULTIPLES OF 100 METRES.

This apparatus, which is shown in Fig. 19, has been designed to facilitate the calibration of wavemeters and wireless receivers. It is intended to work in conjunction with a "power oscillator" of about 10 watts, and as the use of harmonics is involved it is essential that this oscillator should be roughly calibrated.

A single crystal is used having a wavelength (corresponding to its frequency of longitudinal vibrations) of 400 m., and tuned circuits of 400 m., 200 m. and 100 m. can be brought into circuit by means of the switches S_1 and S_2. The third harmonic of 133.3 m. is not used as it gives groups which are not multiples of 100 m. The presence of this undesirable harmonic is reduced to about 25 per cent. of its value by the absorption circuit C_7 L_7.

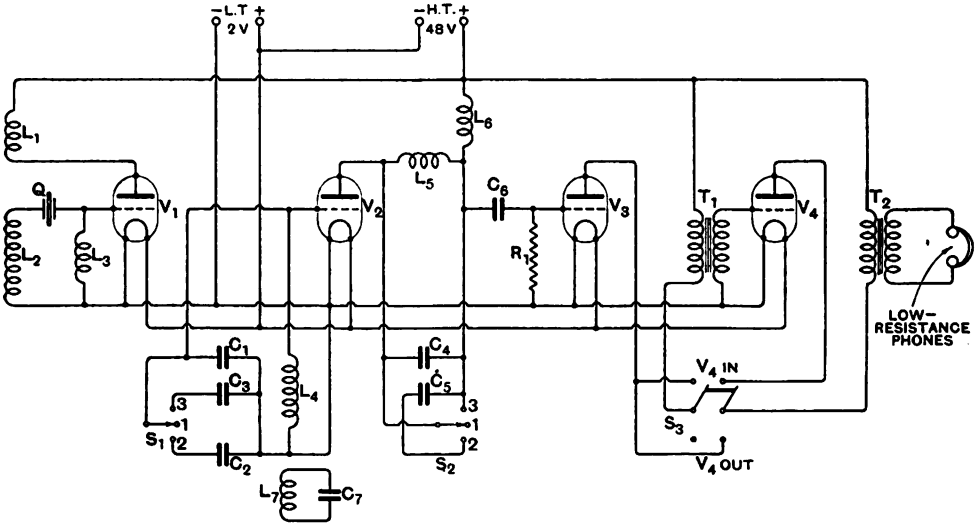


Fig. 19.

The power oscillator can be accurately set to the following wavelengths: Any multiple of 100 m.

up to 1,200 m., when the 4th harmonic is selected; any multiple of 200 m. up to 2,400 m. when the 2nd harmonic is used; any multiple of 400 m. up to 4,800 m. when the fundamental is employed. Other multiples of 100 or 200 m. up to 4,800 m. may also be obtained if the oscillator is sufficiently powerful.

The common batteries provide the necessary coupling between the quartz oscillator and the H.F. valve V_2.

Use of a Quartz Crystal in an Instrument giving a Series of Frequencies that are all Multiples of 1,000 kc.

This instrument, which is called a "crystal multivibrator," is a reference standard of frequencies from 2,000 to 15,000 kc., *i.e.*, 150 to 20 m. Its circuits are shown in Fig. 20. With the exception of the 2-volt accumulator the whole apparatus is contained in a single wooden case.

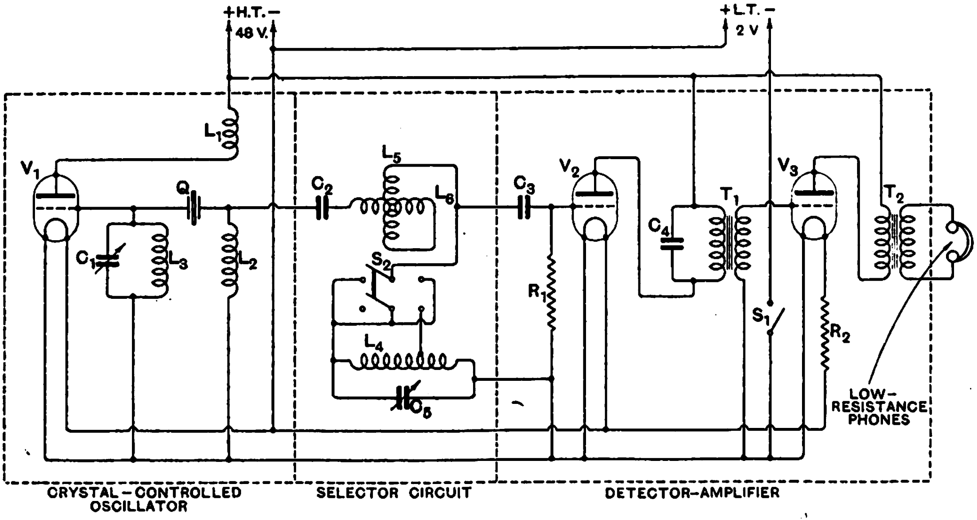


Fig. 20.

The instrument consists of three parts:—

(a) *Crystal controlled oscillator.*—Oscillations of V_1 are controlled at 1,000 kc. by the crystal. The circuit is adjusted so that in the absence of the crystal uncontrolled oscillations of about 3 to 5 per cent. higher are generated. In these conditions the crystal takes control immediately the valve is switched on. Final control of this condition is afforded by C_1, which is a manufacturing adjustment. The crystal is 3 mm. square and 1.5 mm. thick, and vibrates longitudinally at its fundamental frequency.

(b) *Selector circuit.*—This is divided into three sections, brought into operation by the switch S_2 and giving the frequency ranges:—

- Range I. 2 to 5 megacycles (2nd to 5th harmonic).
- Range II. 5 to 12 megacycles (5th to 12th harmonic).
- Range III. 11 to 15 megacycles (11th to 15th harmonic).

The variometer in Range III was found to be a good arrangement for increasing the strength of the high order harmonics.

(c) *Detector Amplifier*, consisting of V_2 and V_3.

Conclusion.

In this concluding section, the authors review some of the advantages, etc., of the quartz crystal. As standards, in comparison with forks, they have the advantage that their natural frequencies are well within the spectrum of wireless frequencies, while in comparison with standard electrical circuits they are more compact and constant, and of lower temperature coefficient.

To obtain greatest possible accuracy, it seems probable that the crystal should be *in vacuo*, while blocks of fused quartz should be used as distance pieces between the electrodes or the air-gap altogether dispensed with by pressing one of the electrodes on to the crystal by means of a light spring.

DISCUSSION.

In opening the discussion, Lt.-Col. A. S. Angwin expressed particular interest in the practical applications of the quartz crystal. Referring to the matter of air-gap, he said that no gap was certainly best for the maximum power, but considerable power could be obtained with a small gap. The Post Office used a metal-to-metal system with micrometer adjustment. He thought the authors were conservative in their estimate of the quartz crystal as a standard of frequency. An oscillator had been described (in proceedings of the I.R.E.) which gave constancy of 1 in one million over a period of 10 days. He queried the authors' use of the name "multivibrator," and suggested "quartz crystal harmonic generator." The use of the term "longitudinal vibrations" was ambiguous as compared with Prof. Cady's original nomenclature.

Col. Aston suggested some uses arising out of the paper. One was in connection with the very small variations of frequency described in the tests carried out by the authors. One important use was the adjustment of several transmitters to exactly the same wavelength. Makers' supplies of crystals were not usually better than 1 in 1,000 accuracy, and he suggested that temperature control might be utilised to get such closer accuracy as suggested by the authors. Thermostatic control could finally maintain constancy of temperature and of frequency. The use of quartz crystals as selective couplings and rejectors was also important. Tests at the I.E.E. indicated a decrement so small as to make the overall circuit too narrow for speech. The use of the crystal as a band-pan filter was thus suggested.

Mr. Lucas referred to the authors' use of longitudinal vibrations. Transverse vibrations were more usual. The fundamental on the longitudinal mode was very marked, but the transverse was more liable to have other frequencies. Early experiments had shown inconstancy as regards frequency and decrement. Tapping of movement altered the constants. Nodal support methods of mounting *in vacuo* gave a great improvement in accuracy, and he showed curves illustrating the improvement in decrement, etc., effected by such mounting.

Capt. Hopkinson also referred briefly to transverse vibrations and to methods of mounting for harmonics.

Lt.-Col. H. Lefroy asked if anything had been done as regards low-frequency applications. He had read of one crystal being caused to oscillate at two (radio) frequencies to produce a beat note.

Mr. Underhill referred to the need for definitions of longitudinal and transverse vibrations. Care in mounting was very necessary. Had the authors noticed that the odd harmonics appeared to be stronger than the even ? With reference to the production of low frequency, singing was sometimes caused by two different frequencies being present due to flaws.

Prof. J. T. MacGregor Morris queried the authors' suggestion that there was no frequency change when there was no air-gap. In insulation tests, both D.C. and A.C., there was great difficulty in getting good contact. In permittivity tests, Dye had found it better to have a definite air-gap. A.C. measurements showed definite capacity and resistance at nominal contacts.

Mr. E. B. Moullin asked for further information as to the effect of the dimensions of the crystals.

Mr. B. Williams referred to early experiments made with crystals on and after Prof. Cady's visit to England in 1923. A crystal controller wavemeter had been in use at the Air Ministry station at Kidbrooke for some years. In the circuit of Fig. 6, minute changes could be got for final frequency adjustment on the tuning condenser. Used as a high-frequency coupling at 3,000 metres, he had found a crystal circuit extremely sharp and capable of operating a relay on a change of a few cycles.

Mr. M. J. Scroggie asked if the authors had observed any effect due to supersonic airwaves in the airgap. Such effects had been known to exist.

Capt. P. P. Eckersley said it was interesting to know that such high constancy was now so easily obtainable. The *source de control* for broadcasting wavelengths had preferred the fork method. As regards the use of the crystal for transmitter control, he said that with a good drive oscillator and care in operation there was no difficulty in obtaining a constancy of 200 in one million, which was enough for present purposes.

Mr. Cobbold briefly replied to the discussion, more especially to points raised by Col. Angwin and Prof. MacGregor Morris.

On the motion of the Chairman (Lt.-Col. A. G. Lee, O.B.E., M.C.), the authors were cordially thanked for their paper.

A demonstration of the " crystal multivibrator " was given after the reading of the paper, various harmonic frequencies being selected. The very different effects of hand capacity on the controlled and the uncontrolled oscillators were very clearly demonstrated.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

The Performance of Valves in Parallel.

To the Editor, E.W. & W.E.

SIR,—In my letter on the above subject which appeared in the January number of *E.W. & W.E.*, I assumed that the fallacy in Mr. Denman's article was so obvious that it would be immediately admitted when once pointed out. As this is not the case, I have carefully reconsidered the position.

I now find that Mr. Denman's treatment is quite correct provided that the flow of current in the valves is continuous. It is then quite possible for the alternating component to be 180° out of phase in individual valves in particular cases. The assumed condition applies to amplifiers under normal conditions of operation.

In the case of transmitting circuits on the other hand it is usual to operate the valves so that the anode current flows during one half of the cycle only, the valves being rendered non-conducting during the other half of the cycle. When valves are operated in parallel on a circuit of this type it is obvious that the pulses of current must occur in all valves simultaneously, and to talk of the currents in individual valves being 180° out of phase would be absurd. It was circuits of this type which I had in mind when I wrote my previous letter.

I must apologise for failing to give the matter more careful consideration in the first instance, but the heading of the article led me to suppose that the results were of universal application and I naturally applied them to the particular case in which I happened to be interested at the moment.

K. E. EDGEWORTH.

Khartoum, Sudan.

Design of Choke Coils and Transformers.

To the Editor, E.W. & W.E.

SIR,—Your article in the issue of February on air gaps in transformers carrying a D.C. component is very interesting, but one must not infer from it that any existing intervalve transformer would of necessity be improved by the introduction of air gaps, for so far as I am aware there is not one on the market which does not contain them.

Considering a favourite form of magnetic circuit which comprises a T on the double width leg of which the windings are placed and a U which completes the circuit, it will be seen that there is one air gap between the leg of the T and the U, and one on each side between the tops of the U and the arms of the T, and the edges are generally so rough that the magnetic resistance is quite considerable.

In the next layer the stampings are reversed so that these joints get covered, but here one has the scale and insulation on the steel to prevent contact.

It will be found that at low frequencies there is a much more scattered field as a result of these air gaps in a transformer made from such stampings than from the same winding placed upon ring punchings of equal volume and cross sectional area, and the effect is very noticeable at 500 cycles, even if there is no secondary winding or load.

No doubt it would be very difficult to construct the counterpart of an ordinary intervalve transformer upon a ring core, but it would be very useful to compare its performance with the latter and see what the air gaps amount to, as it appears impossible to calculate or predict them with any degree of certainty.

Wireless instruments are becoming more and more instruments of precision in the search for quality of reproduction, and possibly an investigation of the kind suggested might help to remove an element of guesswork in design.

WM. A. RICHARDSON.

Ashford, Kent.

Good Quality in H.F. Amplifiers.

To the Editor, E.W. & W.E.

SIR,—With reference to my article in the March issue, I note that you consider 5 per cent. too stringent for the possible reduction in amplification. I think you will agree that if a low-frequency amplifier reduced the higher frequencies by much more than 10 per cent. it would not be considered as first class.

In Carrier Telephony work, where square topped filters are used, the width of the curve is measured six transmission units down, which is equivalent to, roughly, 50 per cent. of the height.

Here, however, intelligibility and not quality is the primary factor, and good intelligibility can be obtained with a band of only 2,000 cycles.

In the case of the ordinary resonance curve, which is not square topped, perhaps 10 per cent. is a fairer figure than 5 per cent., in which case " n " becomes 1.11. Combining the low and high frequency amplifiers, the overall reduction would then amount to about 19 per cent., which is near the limit for really good quality.

C. C. INGLIS.

BOOK RECEIVED.

LEFAX RADIO HANDBOOK. Compiled by Dr. J. H. Dellinger, of the Radio Laboratory, U.S. Bureau of Standards, comprising Introductory Notes, Fundamental Principles, Elements of Receiving and Transmitting Apparatus, Operation of Receiving Sets, Aerials, Tables, and Useful Data and Index; neatly bound in loose-leaf folder so that supplementary sheets may be readily inserted. Published by Lefax, Inc., Philadelphia, Pa. Price $3.50 or with one year's supplements, $7.50.

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

ON A METHOD OF DETERMINING THE STATE OF POLARISATION OF DOWN-COMING WIRELESS WAVES.—E. V. Appleton and J. A. Ratcliffe. (*Proc. Roy. Soc.*, 117A, pp. 576–588, February, 1928.)

The paper is summarised as follows:

1. An experimental method of determining the polarisation constants of ellipticity of down-coming wireless waves is described.
2. The use of the method in a series of measurements in England with 400-metre waves has shown that the down-coming waves are in general elliptically polarised and that the polarisation is approximately circular. The sense of rotation is found to be left-handed.
3. It is shown that, according to the magneto-ionic theory of atmospheric deflection of wireless waves, in which the influence of the earth's magnetic field is recognised, such left-handed elliptical polarisation might be expected if the electrical carriers in the ionised layer are of electronic mass, but that similar measurements made in the Southern Hemisphere would yield evidence which would very materially confirm or disprove such an interpretation.

THE SCATTERING OF WIRELESS WAVES.—T. L. Eckersley. (*Nature*, 18th February, 1928, p. 245.)

Description of the evidence for a very pronounced scattering of wireless waves from the upper regions of the atmosphere which plays a considerable part in short-wave transmission. The writer states that, whatever other conclusions may be drawn from the evidence, it seems certain that the Heaviside layer is by no means a uniformly ionised region, but is very patchy, and there is some evidence of the existence of clouds which are small in dimensions compared with a wavelength of 14 metres.

ON THE INFLUENCE OF SOLAR ACTIVITY ON RADIO TRANSMISSION.—L. Austin and I. Wymore. (*Proc. Inst. Radio Engineers*, 16, pp. 166–173, February, 1928.)

Description of further examination of the daylight long wave signal measurements of the Bureau of Standards for evidence of correlation with solar activity. It has been shown previously that a probable correlation exists between signals and sunspots when the observations are continued for several years and averaged in periods of a month or more. The present paper deals especially with observations averaged in shorter (five-day) periods. While the relationship is generally evident here, it is sometimes obscured by an apparent relative phase shift between the signal and sunspot curves.

THE EFFECT OF WEATHER CONDITIONS ON LONG-DISTANCE RECEPTION.—S. K. Lewer. (*E.W. & W.E.*, 5, pp. 152–161, March, 1928.)

CO-OPERATIVE MEASUREMENTS OF RADIO FADING IN 1925.—J. Dellinger, C. Jolliffe, and T. Parkinson. (*Scientific Papers of the Bureau of Standards*, No. 561, 1927).

Among the results obtained is that fading is at its worst from 60 to 125 miles from a broadcasting station, and has successive maxima and minima at varying distances in excess of the range previously stated. Two readily distinguishable types of fading are recognised, a fairly slow and a relatively rapid fluctuation. The work led to the discovery of a highly regular type of fading, sometimes occurring during the 45 minutes just following sunset, which is evidently due to an interference phenomenon, its period being correlated with the distance between transmitter and receiver.

VARIATIONS OF ATMOSPHERIC PRESSURE AS A POSSIBLE CONTRIBUTING CAUSE OF STATIC, OF EARTH CURRENTS AND THEIR VARIATIONS, AND OF VARIATIONS ON THE EARTH'S MAGNETIC FIELD.—R. Hamer. (*Physical Review*, 31, p. 156, January, 1928.)

Abstract of a paper presented at the Chicago meeting of the American Physical Society, November, 1927.

A vertical glass tube filled with moist earth formed part of a closed circuit including a sensitive galvanometer. Sudden changes of air pressure caused variations to occur in the current which flowed due to electrolytic action in the soil acids at the electrodes. To eliminate effects due to pressure changes causing variations of soil resistance, the electrodes were insulated by glass dishes, one end earthed and the tube shielded. The insulated top electrode was connected to a quadrant electrometer. Similar pressure changes cause the electrometer to indicate the presence of a temporary charge at the electrodes. Apparently a temporary disturbance takes place in the distribution of the electrons or ions in the earth when sudden changes of air pressure occur. It is suggested that earth current measurements may be influenced by these two effects. The experiments also seem to afford obvious explanations of the many various known facts peculiar to the propagation of radio waves, especially in the case of reception. Possibly barometric changes cause variations in earth currents directly, and also indirectly by varying surface soil resistance. If these are large enough to produce observable magnetic effects, they may explain why magnetic variations seem to parallel those of earth currents.

IONISATION IN THE UPPER ATMOSPHERE.—E. O. Hulburt. (*Proc. Inst. Radio Engineers*, 16, pp. 174–176, February, 1928.)

Abstract of a paper read at the open meeting of the U.R.S.I., Washington, October, 1927.

The author re-examines the causes of ionisation in the upper atmosphere in the light of recent radio data and theory, and concludes that the sun's ultra-violet light is a necessary and sufficient cause of the Kennelly-Heaviside layer. The experiments are found to show that the electron density increases with the height above the earth, reaching a maximum value of about 4×10^6 at a height in the daytime of 150 to 200 km., above which the value of the electron density is not known, except that it does not go on increasing. The author emphasises the view that he can see no possibility of the existence of electron banks above the main one having its maximum electronic density at a height around 150–200 km. and therefore that inferences from radio data which suggest the presence of such outlying layers must be examined with care before they can be accepted.

Cf. Nature, 6th August, 1927, p. 187 (these Abstracts, October, 1927, p. 634).

EXPERIMENTS AND OBSERVATIONS CONCERNING THE IONISED REGIONS OF THE ATMOSPHERE.—R. A. Heising. (*Proc. Inst. Radio Engineers*, 16, pp. 75-99, January, 1928.)

Experiments are described in which a virtual height of the reflecting ionised region was measured using time lag between impulses arriving over a direct, and the reflected path. The measurements were made on 57 and 111 metres. The height was ascertained only at night and the daylight hour before sunset. Movements of the reflecting region are plotted showing slow rises and rapid drops. The rising rate approximates 6 miles a minute, and the falling rate 20 miles a minute. Multiple reflections were observed. Transmission measurement curves are given showing dependence of 16-7/8 metre signals on the night ionisation, and the assistance that sunlight ionisation can give. Experiments and curves are mentioned that show absorption to be one of the important factors causing poor daylight transmission in the wavelength region contiguous to 214 metres. It is pointed out that the absorbing region is below the refracting region and that the sky wave must make two passages through the absorbing region. It is shown that both electromagnetic waves from the sun, and β particles, must be assumed as producers of ionisation to explain phenomena observed. On this theory the electromagnetic waves from the sun produce the ionisation in the absorbing region, and part of the day ionisation in the refracting region. This ionisation is pictured as beginning at an altitude of about 16 miles and extending upward, and as experiencing diurnal and seasonal variations. The β particles produce, at an altitude higher than the absorbing region, further ionisation which is the principal ionisation at night due to the absence of the electromagnetic ionisation. This ionisation is pictured as occupying part of the same region as the electromagnetic ionisation and being very irregular in intensity and position.

THE PROPAGATION OF RADIO WAVES ALONG THE SURFACE OF THE EARTH AND IN THE ATMOSPHERE, BY PROFESSOR P. O. PEDERSEN.—J. C. Rybner. (*Proc. Inst. Radio Engineers*, 16, pp. 219-223, February, 1928.)

A comprehensive review of this book, dealing with the various chapters in detail, and outlining the connected physical theory of wave propagation there given.

SUR L'INTERPRÉTATION DE RÉSULTATS EXPÉRIMENTAUX RELATIFS AUX PROPRIÉTÉS DIÉLECTRIQUES DES GAZ IONISÉS. (On the interpretation of some experimental results concerning the dielectric properties of ionised gases.)—H. Gutton. (*L'Onde Electrique*, 7, pp. 1-4, January, 1928.)

In *L'Onde Electrique* for April, 1927, p. 137 (these Abstracts, September, 1927, p. 572), the author described experiments which led him to conclude that, when the ionisation of a gas is great, it is no longer possible, as in Eccles' theory, to assume that the mutual action of the ions does not come in, and the apparent diminution of the dielectric constant of the gas does not remain proportional to the number of ions per c.c.

In a memoir by P. O. Pedersen, entitled "The propagation of radio waves along the surface of the earth and in the atmosphere," several pages are devoted to these experiments, and they are explained without modifying Eccles' theory.

This explanation does not appear to the author to agree with the experimental results, which he outlines again here, and which he still maintains show that Eccles' theory is only valid for weak ionisation, the weaker the longer the wavelength, and that mutual action between the ions is necessary to explain the experimental phenomena described.

A THEORY OF THE UPPER ATMOSPHERE AND METEORS.—H. B. Maris. (*Proc. Inst. Radio Engineers*, 16, pp. 177-180, February, 1928.)

A calculation of the rate of separation of gases of different density in the earth's atmosphere leads us to expect a uniform mixture of all gases below 100 km., and for greater heights, densities of hydrogen and helium roughly a hundred thousandth of those previously calculated. Known absorption and radiation coefficients for gases of the upper atmosphere indicate that we should expect a daily temperature variation of about 140° during the summer and 30° during the winter for all heights greater than 80 km.

A RADIO FIELD STRENGTH SURVEY OF PHILADELPHIA.—K. McIlwain and W. Thompson. (*Proc. Inst. Radio Engineers*, 16, pp. 181-192, February, 1928.)

The method and apparatus are described and the results discussed, the field strength contour map of Philadelphia obtained being reproduced.

RADIO COMMUNICATION.—G. Marconi. (*Proc. Inst. Radio Engineers*, 16, pp. 40-69, January, 1928.)

An address delivered before the American Institute of Electrical Engineers and Institute of Radio Engineers, New York City, 17th October, 1927. A brief historical sketch of the investigations carried out by the author and his assistants on short waves, describing some of the strides that have already been made in their application to radio communications over long distances.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

CHANGES IN THE ELECTRIC FIELD DUE TO LIGHTNING DISCHARGES.—J. Jensen. (*Physical Review*, 31, p. 312, February, 1928.)

Abstract of a paper presented at the Nashville meeting of the American Physical Society, December, 1927.

Further investigations confirm previous results and are in agreement with the conclusions of Wilson and of Schonland and Craib, that the lower pole of thunderclouds usually carries a negative charge. It is stated that photographs of individual flashes in some cases show a branching towards the earth, which is in contradiction to Simpson's theory; the thin and rambling branches suggesting the electronic darts mentioned by Dorsey as feeding into the main discharge path.

LA SISMICITÉ DU SOLEIL ET LA PÉRIODICITÉ DES ORAGES MAGNÉTIQUES (The sun's "seismicity" and the periodicity of magnetic storms).—E. Belot. (*Comptes Rendus*, 185, pp. 1259–1261.)

In a recent series of articles, M. Deslandres has enunciated the law of periodicity of magnetic storms due to the emission of ions and electrons by layers deep within the sun, where volcanoes spaced by 60° are found along the equatorial zone. Besides these six most intense storm centres, there are secondary periodicities coming from emissions at 30° and 15° to them, marking less important magnetic storms. This paper investigates the causes for these periodicities.

PROPERTIES OF CIRCUITS.

GRID CURRENT MODULATION.—E. Peterson and C. R. Keith. (*Bell System Technical Journal*, 7, pp. 106–139.)

A paper discussing some of the properties of a type of modulator utilising the non-linear relation existing between grid voltage and grid current, and the advantages recent laboratory investigation indicates that it may possess.

The term grid current modulator is used to describe those valve circuits in which modulation is initially produced in the grid circuit of a three-electrode valve due to the non-linear grid current-grid voltage relation. Comparison with a representative plate current modulator using the same valves and the same plate potential shows that by modulating at maximum efficiency in the grid circuit and using the plate circuit solely for amplification, the maximum power output is increased about eight times, the power efficiency about five times, and the ratio of side-band output to signal input approximately three times. Under these conditions more carrier input power is needed for the grid than for the plate modulator.

Normally modulation is also produced in the plate circuit, which is shown to be out of phase with that produced in the grid circuit. By inserting high impedances to the input frequencies in the plate circuit, plate circuit modulation is prevented, and the reduction of grid circuit side-band is likewise avoided. By including in the grid circuit an impedance which is high to the desired side-band frequencies, the maximum grid side-band voltage is obtained. In this way the power and modulating efficiencies of the valve circuit are made a maximum.

Where modulation occurs only in the plate circuit of a valve, the side-band amplitude is proportional to the product of the amplitudes of the input frequencies when these amplitudes are small. In the present type of grid current modulator the side-band amplitude is proportional to the smaller of the two input amplitudes provided the ratio between these is greater than about 3/2. This feature makes the modulator particularly valuable in communication systems.

LES CIRCUITS À DEUX ONDES ET LEURS APPLICATIONS (Two-wave circuits and their applications).—L. Brillouin and E. Fromy. (*L'Onde Electrique*, 6 and 7, pp. 561–579 and 33–39, respectively.)

In a previous paper (*O.E.*, 5, pp. 371 and 419), the authors investigated the general problem of poly-wave circuits and showed that in the particular case of two-wave resonance, a large number of circuits could be produced, reducible to eleven characteristic types, themselves grouped into three classes.

In the present paper, these three classes are more especially studied, and are given a form able to furnish a practical means of realising two-wave circuits. Investigation is first made of the modes of vibration of these two-wave circuits, utilising a graphical method. The conclusion drawn from this first part is that it is always possible to arrange the circuits so that the oscillations on each of the two waves are localised in certain parts peculiar to them, the adjustments of the complex circuit on the two waves being thus mutually independent. In practice, with two simple types of circuit supplementing one another, resonance can be effected on any two waves, whether near one another or very far apart. By means of electric or magnetic coupling with one or two coils, one can very easily couple a complex circuit to any other circuit, arranging so that the coupling is strictly nil for one of the waves and normal for the other, from which there results the possibility of effecting complete selection of the two waves and considerable flexibility in the adjustments.

These general considerations lead to the statement of principles for constructing two-wave antennæ, capable of being connected to receivers or transmitting valves and providing simple means of producing simultaneously on the same antenna, either two independent transmissions or receptions or one reception and one transmission.

WEITERER BEITRAG ZUR NEGADYNSCHALTUNG (Further contribution on the negadyne circuit-arrangement).—E. Mittelmann. (*Zeitschr. f. Hochfrequenz.*, 30, pp. 157–160, November, 1927.)

By taking the lead of the space charge grid to the oscillatory circuit in the negadyne arrangement, the back-coupling can be suppressed to the extent that the unstable state previous to the starting to oscillate is only attained with pretty high heating values. A high anode direct current is thus rendered possible. By inserting a choke of sufficiently high inductance in the anode circuit, the tendency of the valve to oscillate becomes still further checked.

A STUDY OF THE RECTIFICATION EFFICIENCY OF THERMIONIC VALVES AT MODERATELY HIGH FREQUENCIES.—W. E. Benham. (*Philosophical Magazine*, 5, pp. 323-334, February, 1928.)

Description of experiments with a diode which show that:

(*a*) For a given input voltage amplitude, the rectified current is in general different at different frequencies, the frequencies employed in the experiments lying between 4.1 and 16.8 megacycles ($\lambda 73$-$\lambda 17.8$ metres).

(*b*) The value of input voltage amplitude at which departure from square law rectification takes place decreases as the frequency is increased.

The form of the frequency variation is investigated in detail in the case where the input voltage amplitude is small enough for rectification to take place according to a square law. In this case the rectified current falls off as the frequency is increased, the rate of variation being markedly affected by the filament temperature.

Experiments with a helium-filled valve used as a triode show a variation of similar form and magnitude for plate voltages below the critical potential, the variation corresponding, however, to an increase with frequency as distinct from the decrease with a two-electrode valve. For plate voltages above the critical potential, the variation with frequency is much more rapid, doubtless due to the presence of slowly-moving ions; at a certain frequency, depending on the potential, the rectified current is zero, the rectified current due to the space-charge being neutralised by a similar current due to the helium ions. At a higher frequency (about $N = 14$ megacycles) the rectified current is the same as it would be in the absence of helium ions; in other words, there is no rectification due to helium ions in the neighbourhood of this frequency.

PARASITIC OSCILLATIONS IN THE CASE OF A TUNED-ANODE OSCILLATOR.—M. Reed. (*E.W. & W.E.*, 5, pp. 135–147, March, 1928.)

SOME EXTENSIONS OF THEORY AND MEASUREMENTS OF SHOT-EFFECT IN PERIODIC CIRCUITS.—H. B. Vincent. (*Proc. Nat. Acad. Sciences*, 13, pp. 774–785.)

TRANSMISSION.

ÜBER DIE VON EINEM ABREISSENDEN MODULIERTEN UNGEDÄMPFTEN SENDER GELIEFERTE SCHWINGUNGSFORM (On the form of oscillation yielded by an interrupted modulated continuous wave transmitter).—F. A. Fischer. (*Zeitschr. f. Hochfrequenz.*, 30, p. 188, December, 1927.)

While a modulated high-frequency oscillation is in general an aperiodic phenomenon, the oscillation afforded by an interrupted modulated continuous wave transmitter is always periodic. In general, however, the "carrier frequency" does not occur below the partial oscillations. The two phenomena are identical only in the particular case when the modulation frequency is a whole multiple of the carrier frequency.

GENERALISED THEORY OF ANTENNÆ.—R. M. Wilmotte. (*E.W. & W.E.*, 5, pp. 119–131, March, 1928.)

BERMERKUNGEN ZU DER ARBEIT VON HORST WINKLER "ZIEHERSCHEINUNGEN BEIM LICHTBOGENSENDER" (Remarks on Horst Winkler's paper, "Oscillation hysteresis phenomena in the case of arc transmitters").—W. Burstyn. (*Zeitschr. f. Hochfrequenz.*, 30, p. 167, November, 1927.)

Winkler observes in his paper (this *Zeitschr.*, July, 1927; these Abs., November, 1927, p. 695) that all investigation of oscillation hysteresis phenomena hitherto has been confined to the special case of the valve transmitter. Burstyn here states it must have escaped Winkler's notice, that in *E.T.Z.* of 2nd December, 1920, there was a paper by him, "Coupling Phenomena with Continuous Oscillations," in which oscillation hysteresis phenomena in arc transmitters are fully discussed. Moreover, Burstyn claims to have discovered the phenomena, quoting a passage from *E.T.Z.* of 26th June, 1913, to that effect.

NOTE SUR LE CHOIX PRÉLIMINAIRE DES CONSTANTES ELECTRIQUES D'UNE ANTENNE PSEUDO-SYMÉTRIQUE (Note on the preliminary choice of the electric constants of a pseudo-symmetrical antenna.—M. Waserman (*L'Onde Electrique*, 7, pp. 40–44, January, 1928.)

RECEPTION.

A HIGH-EFFICIENCY RECEIVER FOR A HORN-TYPE LOUD-SPEAKER OF LARGE POWER CAPACITY.—E. C. Wente and A. L. Thuras. (*Bell System Technical Journal*, 7, pp. 140–153.)

Description of a telephone receiver of the moving coil variety, which is particularly adaptable to the horn type of loud-speaker, and whose design is such as to permit of a continuous electrical input of 30 watts as contrasted with the largest capacity previously available of about 5 watts. Further, the receiver has a conversion efficiency from electrical to sound energy varying between 10 and 50 per cent. in the frequency range of 60 to 7,500 cycles. Throughout most of this range, its efficiency is 50 per cent. or better, which is contrasted with an average efficiency of about 1 per cent. for other loud-speakers either of the horn or cone type.

A RADIO-RECEIVING OSCILLATOR FOR RECEIVER INVESTIGATIONS.—G. Rodwin and T. Smith. (*Proc. Inst. Radio Engineers*, 16, pp. 155–165, February, 1928.)

Description of a modulated radio-frequency oscillator. The apparatus incorporates a means for obtaining radio-frequency outputs of widely varying range, a metering system, a means for changing the generated frequency in small steps to either side of a given frequency, and a modulation and indicating system.

Good Quality in H.F. Amplifiers.—C. Inglis. (*E.W. & W.E.*, 5, pp. 132–134, March, 1928.)

What is the Correct Characteristic for a Variable Condenser ?—K. E. Edgeworth. (*E.W. & W.E.*, 5, pp. 148–150, March, 1928.)

Anode Bend or Grid Rectification ?—A. P. Castellain. (*Wireless World*, 22, pp. 188–190, 22nd February, 1928.)

Some practical data on their relative merits.

Un 4 Valvole di Uso Generale (A 4-valve general purpose receiver).—U. Guerra. (*Radio Tecnica*, 1, pp. 28–36, February, 1928.)

Description of this instrument employing a screened valve.

Zusammenfassender Bericht : Der Kristalldetektor (The crystal detector : survey of the subject).—A. Schleede and H. Buggish. *Zeitschr. f. Hochfrequenz.*, 30, pp. 190–193, December, 1927.)

Recent investigation of the detector problem leads to an explanation of certain contradictions previously existing in the literature of the subject. In the case of galena and partly also with pyrites, it is shown that :

1. Sensitive crystals are differentiated from insensitive ones by their chemical composition. While insensitive galena approximately corresponds to the theoretical composition, sensitive galena exhibits a relative excess of sulphur and deficiency in lead by about 1 to 2 per cent.
2. The existence of places of varying sensitivity in a piece of naturally occurring galena is to be attributed to the fact that even pieces which look homogeneous from the outside are really made up of separate crystals of varying sensitivity.

It is stated, however, that the observations do not render possible a definite decision between the different explanations of the rectifier effect that have been advanced, although the excess of sulphur discovered in sensitive galena points distinctly to the electronic theory.

Sur une Anomalie dans le Fonctionnement des Détecteurs à Contact et sur ses Conséquences (On an anomaly in the operation of contact detectors and its consequences).—J. Groszkowski. (*L'Onde Electrique*, 6, pp. 554-558, November, 1927.)

Investigation of the existence of an anomaly in the working of the contact detector, due to the particular shape of its static characteristic. The irregularity is indicated by the variable behaviour of the dynamic characteristic, it being possible to obtain a certain value for the rectified current for different values of the tension being rectified. The author considers the conditions under which this anomaly can occur and its consequences.

VALVES AND THERMIONICS.

New Valve Rectifier.—A. Gehrts. (*Siemens Zeitschrift*, August, 1927.)

The new valve has a cathode made from thorium-coated molybdenum placed between two tantalum anodes and represents therefore a two-way valve. The chief claims for the new cathode material are that it is insensitive to temperature changes of several hundred degrees and is not affected by the bombardment of positive ions.

Die Entwicklung im Elektronenröhrenbau (Development in valve construction).—H. Simon. (*Zeitschr. f. techn. Physik.*, 11, pp. 434–445, November, 1927.)

A paper presented at the meeting of German physicists at Bad Kissingen, September, 1927.

An account of the progress in valve construction made in the last year, referring particularly to the work done in the laboratories of the Telefunken Company. Study is made of the material for filament, grid and anode ; of automatic mounting and exhausting ; the construction of valves for specific purposes ; and noise in transmitting valves and its elimination.

Cf. also *Telefunken-Zeitung*, 47, pp. 38–50.

Die technische Herstellung von Oxydkathoden (Industrial production of oxide cathodes).—W. Statz. (*Zeitschr. f. techn. Physik.*, 8, pp. 451–456.)

Discussion of different methods of producing oxide cathodes with their advantages and drawbacks.

Kleingleichrichter für Rundfunkzwecke (Small rectifiers for broadcast purposes).—M. Bareiss. (*Zeitschr. f. techn. Physik*, 8 pp. 449–451.)

Physical and technical particulars are given of the construction of different kinds of small-power rectifying valves.

The Overshooting of the Temperature of a Tungsten Filament.—L. Bockstahler. (*Physical Review*, 31, p. 303, February, 1928.)

Using a double strip oscillograph, simultaneous photographic records were made of the heating current in a straight filament tungsten lamp and the thermionic current emitted by the central portion of the filament. The records showed that, on closing the circuit, the expected momentary overshooting of the heating current was followed by a marked overshooting of the thermionic current, Since the thermionic current indicated the temperature of the filament, there was an overshooting of the power consumption when the current was turned on the cold filament. The magnitude and duration of the surge depends on the final temperature and size of the filament.

On Electrical Fields near Metallic Surfaces.—J. Becker and D. Mueller. (*Physical Review*, 31, p. 308, February, 1928.)

If an electron must pass through surface fields in order to escape from the surface, a properly directed applied field, F, should partially neutralise the surface fields and hence increase the thermionic current i. A simple analysis shows that $d(\log_{10} i)/dF = (11{,}600/2.3T) \times S$, where T = surface temperature and $S =$ distance from the surface at which the surface field equals F. For clean surfaces the observed current-voltage relation can be accounted for if the only force acting on the escaping electron is due to its image field. For composite surfaces such as thorium on tungsten, another field due to the adsorbed ions is superposed on the image field. Close to the surface this " adsorption field is very intense and helps electrons escape, thus decreasing the work function; farther from the surface this field reverses sign, grows to a maximum value and then steadily decreases. This reverse field has appreciable values at surprisingly large values of S. Hence the logi — F curve for composite surfaces is steeper than that for clean surfaces.

The Photo-electric and Thermionic Work Functions of Outgassed Platinum.—L. Du Bridge. (*Physical Review*, 31, pp. 236-243, February, 1928.)

Description of an investigation which establishes agreement between the photo-electric and thermionic work functions for outgassed platinum and finds the thermionic constant A for cleaned platinum very considerably greater than that required by Dushman's theory.

A Comparison of the Thermionic and Photo-electric Work Functions for Clean Tungsten.—A. H. Warner. (*Proc. Nat. Acad. Sciences*, 13, pp. 56-60.)

Thermionic Emission and the " Universal Constant " A.—E. H. Hall. (*Proc. Nat. Acad. Sciences*, 13, pp. 315-326.)

The Restored Electron Theory of Metals and Thermionic Formulæ.—R. H. Fowler. (*Proc. Roy. Soc.*, 117A, pp. 549-552, February, 1928.)

Photo-electric Emission, Thermionic Emission and Peltier Effect.—E. H. Hall. (*Proc. Nat. Acad. Sciences*, 13, pp. 43-46.)

ritical Primary Velocities in the Secondary Electron Emission of Tungsten.—H. Krefft. (*Physical Review*, 31, pp. 199-214, February, 1928.)

DIRECTIONAL WIRELESS.

Rotating-Beacon Radio Transmitters.—(*E.W. & W.E.*, 5, pp. 85-93, February, 1928.)

Abstracts of three papers read before the Wireless Section of the Institution of Electrical Engineers, January, 1928.

Untersuchungen über die Peilbarkeit kurzer Wellen bei Tag und Nacht. (Experiments on the possibility of taking bearings on short waves by day and night.—F. Michelssen. (*Zeitschr. f. Hochfrequenz.*, 30, pp. 183-187, December, 1927.)

Account of an investigation on the usefulness of waves shorter than 100 metres for taking bearings, which was carried out by the Telefunken Company in conjunction with the Marine Service during the summer of 1926.

The experiments were described in *Telefunken-Zeitung*, 44 and 45-46, and the results summarised in these Abstracts, *E.W. & W.E.*, November, 1927, pp. 698 and 699. The conclusion reached was that the use of short waves for taking bearings is not at present practicable.

Die Vergrösserung des Empfangsbereiches bei Doppelrahmen undDoppelcardioidenanordnungen durch Goniometer. (Increasing the range of reception with double frames and cardiode-arrangements by means of goniometers.)—A. Esau. (*Zeitschr. f. Hochfrequenz.*, 30, pp. 141-151, November, 1927.)

Description of receiving arrangements consisting either of frames or cardiode systems, with which, by employing goniometers in the subsidiary and principal systems, reception is rendered possible from all directions and not only from that given by the base-line of the antennæ, as previously, without prejudicing the freedom from disturbance. The necessary condition for this is that the ratio

$$\frac{\text{spacing of the antennæ}}{\text{wavelength}}$$

is chosen small.

Cf. " Directional characteristics of antenna combinations, Esau, *Zeitschr. f. Hochfrequenz*, 27, p. 142; 28, pp. 1 and 147 (these Abstracts, September, 1926, p. 570; and March, 1927, p. 179).

Kurzwellenpeilversuche mit Rahmen und Hilfsantenne auf grössere Entfernungen über See. (Experiments on short-wave direction-finding, with frame and auxiliary antenna, over greater distances, over sea.—F. A. Fischer. (*Zeitschr. f. Hochfrequenz.*, 30, pp. 188-189, December, 1927.)

Supplementing the investigation of 1926, referred to above, in June of 1927, the experiments were carried out over greater distances. This time the direction-finder was on land near the coast, while a 150-watt transmitter was erected on a ship. Since the experiments in the previous year had shown that as wide a frequency band as possible considerably lightened the work with short waves, the transmitter was again run with alternating anode tension. The direction-finding apparatus was that developed by Telefunken for the previous experiments: a frame with auxiliary antenna, forming the grid circuit coil of a push-pull receiver. The wavelengths investigated were 49, 39, 28.5 and 19 metres, and the distance ranged between 30 and 570 sea miles. The results are comprehensively tabulated.

These show that at a distance of 30 miles, bearings could be taken on waves as short as 19 metres. At 85 miles, the vanishing of the surface wave and appearance of the space wave were distinctly observable. The surface wave, of course, first disappears for the smallest wave and the effect of the space wave first appears with the longer waves. At 130-230 miles, the longer waves became successively unemployable, while silent zones occurred with the smaller waves. From 230 miles onwards, it was clearly only a question of pure space radiation with all waves. Either direction-finding was entirely impossible, or the minimum was very broad and wandered slowly through large angles. This wandering first begins with distances over 200 miles, which accounts for its not being observed in the summer of 1926. The waves of 28.5 and 19 metres were received over these greater distances only by day, but then sometimes with exceptional strength.

MEASUREMENTS AND STANDARDS.

PRECISION DETERMINATION OF FREQUENCY.—J. Horton and W. Marrison. (*Proc. Inst. Radio Engineers*, 16, pp. 137-154, February, 1928.)

Paper read at a meeting of the U.R.S.I., Washington, October, 1927, summarised as follows:

The relations between frequency and time are such that it is desirable to refer them to a common standard. Reference standards, both of time and of frequency, are characterised by the requirement that their rates shall be so constant that the total number of variations executed in a time of known duration may be taken as a measure of the rate over shorter intervals of time. Frequency standards have the further requirement that the form of their variations and the order of magnitude of their rates shall be suitable for comparison with the waves used in electrical communication.

Two different types of standard meeting these requirements are described; one consisting of a regenerative valve circuit, the frequency of which is determined by the mechanical properties of a tuning fork, and the other a regenerative circuit controlled by a piezo-active crystal.

Data taken over a period of several years with a fork-controlled circuit show that, under normal conditions, its rate may be relied on to two parts in one million. Data taken over a much shorter time with crystal-controlled oscillators indicate that they are about ten times as stable.

A PRECISION METHOD FOR THE MEASUREMENT OF HIGH FREQUENCIES.—C. B. Aiken. (*Proc. Inst. Radio Engineers*, 16, pp. 125–136, February, 1928.)

Consideration of a precision method for measuring the frequency of an oscillatory circuit. The theory of the method is discussed and an equation developed relating the frequency of the beat note between two oscillators to the natural frequency of a circuit which is loosely coupled to one of them. This equation is considered in some detail and certain of its properties are deduced. Curves are drawn for three typical cases. The causes and avoidance of certain errors are considered. The method is extended to the case of a non-oscillating circuit. Lastly, a method is suggested for the measurement of small values of mutual inductance.

CONDENSER SHUNT FOR MEASUREMENT OF HIGH-FREQUENCY CURRENTS OF LARGE MAGNITUDE.—A. Nyman. (*Proc. Inst. Radio Engineers*, 16, pp. 208–217, February, 1928.)

Description of a new precision device, consisting of a large condenser in parallel with a small one, the latter carrying the current to a small thermocouple ammeter. The construction of the device includes provisions for reducing and restricting the electrostatic and electromagnetic field, due to large current; the reduction of distributed inductance and capacity; the prevention of the resonance effect of high harmonics in the operating current; and the location of the measuring instrument at a distance from the circuit. Large ratings are possible by connecting a number of condenser units in parallel.

A TRIODE AMPLIFIER FOR SMALL DIRECT CURRENTS.—A. Marcus. (*Physical Review*, 31, p. 302, February, 1928.)

Abstract of a paper presented at the Nashville meeting of the American Physical Society, December, 1927, describing a type of "thermionic galvanometer" which is being employed to measure ionisation currents, photo-electric currents, and piezo-electric currents of magnitudes considerably below the range of the galvanometer when used without the triode.

ELECTRICAL MEASUREMENT OF COMMUNICATION APPARATUS.—W. J. Shackelton and J. G. Ferguson. (*Bell System Technical Journal*, 7, pp. 70–89, January, 1928.)

A paper presented at the A.I.E.E. meeting at Pittsfield, May, 1927, describing precision high-frequency measurements of a fundamental type. Standards of frequency, resistance, capacitance and inductance are briefly discussed and bridge methods of measuring frequency, inductance, effective resistance, capacitance, dielectric loss, etc., described.

HOW BROADCASTING WAVELENGTHS ARE CHECKED. R. Braillard and E. Divoire. (*Wireless World*, 22, pp. 219–222, 29th February, 1928.)

Description of the international listening station at Brussels.

ON THE DETERMINATION OF THE PIEZO-ELECTRIC CONSTANT OF A QUARTZ RESONATOR AT HIGH FREQUENCY.—T. Fujimoto. (*Physical Review*, 31, p. 312, February, 1928.)

Abstract of a paper presented at the Nashville meeting of the American Physical Society, December, 1927.

THE USE OF THE CATHODE-RAY OSCILLOGRAPH IN THE STUDY OF RESONANCE PHENOMENA IN PIEZO-ELECTRIC CRYSTALS.—K. S. Van Dyke. (*Physical Review*, 31, p. 303, February, 1928.)

Abstract of a paper presented at the Nashville meeting of the American Physical Society, December, 1927.

The piezo-electric resonator in series with a known resistance A forms one side of a bridge, while the other side consists of a known impedance in series with a second known resistance B. The deflecting systems of the cathode-ray oscillograph are connected so that one indicates the potential across A and the other that across B. When a source of alternating potential whose frequency is independent of any reaction from the resonator is applied to the bridge, the oscillograph indicates by a Lissajous figure the relative magnitudes and phases of the currents in the two arms. The impedance of the resonator at frequencies near resonance may be computed from measurements on the figure for those frequencies, and the constants of the electric network equivalent of the resonator obtained therefrom.

THE POWER-FACTOR AND CAPACITY OF THE ELECTRODES AND BASE OF TRIODE VALVES WITH SPECIAL REFERENCE TO THEIR USE IN THERMIONIC VOLTMETERS.—G. W. Sutton. (*Proc. Phys. Soc.*, 40, pp. 14-22, December, 1927.)

Discussion of the conditions under which a three-electrode valve-voltmeter should be operated to ensure a minimum power consumption, and at the same time give indications closely proportional to the square of the input voltage. A simple method of adjusting the operating voltages to fulfil the necessary conditions is described.

THE USE OF THE GRID-GLOW TUBE AS AN ELECTROSTATIC VOLTMETER.—T. Wilkins and F. Friend. (*Physical Review*, 31, p. 301, February, 1928.)

Abstract of a paper presented at the Nashville meeting of the American Physical Society, December, 1927.

DIE BERECHNUNG DER AKUSTISCHEN EIGENSCHAFTEN DES KONDENSATORMIKROPHONS (Calculating the acoustic properties of the condenser microphone.—A. J. Jakowleff. *Zeitschr. f. Hochfrequenz.*, 30, pp. 151-157, November, 1927.)

The theory of the condenser microphone is given and a method for its calculation. The theory shows that the condenser microphone permits reproduction of speech without amplitude distortion if

1. The membrane has as high a natural frequency as possible and, at least, is two or three times higher than the highest frequency to be reproduced by the microphone;
2. The damping factor equals 1.35 times the natural frequency.

It is seen, however, from the calculation, that only the first requirement is capable of fulfilment, the second one not being so.

Lastly, a theoretical curve for the condenser microphone is shown and compared with the curves obtained experimentally by F. Trendelenburg and E. C. Wente.

DISPERSIONSMESSUNGEN IM GEBIETE KURZER ELEKTRISCHER WELLEN (Dispersion measurements in the region of short electric waves). —W. Heim. (*Zeitschr. f. Hochfrequenz.*, 30, pp. 160-167 and 176-183, November and December, 1927.)

The method of Barkhausen and Kurz is applied to the production of short undamped electric waves for dispersion measurements according to the first and a modified second Drude method. In the first part of the paper the theory of these two methods is developed after a process borrowed from cable theory. In the second part the experimental arrangement is described. The external circuits of the valve generator are in the form of parallel wire systems and, with moving bridges permit the production of waves from $\lambda/2 = 18$ cm. up to $\lambda/2 = 160$ cm. The oscillations are transferred to the measuring arrangement by means of a tuned parallel wire system. The third part gives the results. The dielectric constant of water was determined at various frequencies in the given wave range, but no anomalous dispersion was found, while glycerine gave the dispersion drop calculated by Debye.

NOUVELLE MÉTHODE POUR LA MESURE ABSOLUE, EN HAUTE FRÉQUENCE, DES CONSTANTES DIÉLECTRIQUES DES LIQUIDES (A new method for the absolute measurement of the dielectric constant of liquids, at high frequency).—R. Darbord. (*Comptes Rendus*, 185, pp. 1193-1195.)

ELECTRICAL RESISTANCE AND MAGNETIC PERMEABILITY OF IRON WIRE AT RADIO FREQUENCIES.—G. Wait, F. Brickwedde, and E. Hall. (*Physical Review*, 31, p. 303, February, 1928.)

While Mitiæv observed that the high-frequency resistance of iron wire undergoes a critical change at about 100 metres wavelength, and Wwedensky and Theodortschik a critical change in permeability of iron, the authors have repeated the experiments and find no critical variation.

SUBSIDIARY APPARATUS AND MATERIALS.

AN IMPROVED FORM OF CATHODE RAY OSCILLOGRAPH.—R. H. George. (*Physical Review*, 31, p. 303, February, 1928.)

Abstract of a paper presented at the Nashville meeting of the American Physical Society, December, 1927, describing an oscillograph designed for maximum flexibility. It is constructed almost entirely of metal, and arranged for inserting photographic plates and films in the vacuum to obtain permanent records of transient phenomena. By employing interchangeable cathode parts the accelerating potential of the beam can be varied from less than 100 volts to thousands of volts, depending on the deflectional and photographic sensitivity required. The deflecting plates are adjustable, and as many as three pairs can be used at one time, making possible three simultaneous deflections by electrostatic fields. Magnetic deflecting coils may also be employed when desirable.

A TWO-RANGE VACUUM TUBE VOLTMETER.—C. Jansky, Jr., and C. Feldman. (*Journal Amer. Inst. Elect. Eng.*, 47, pp. 126–132, February, 1928.)

Discussion of the design, uses and limitations of a new circuit employing the three-element vacuum tube as a voltmeter. The unique features are two overlapping ranges of voltage and a single operating battery. The effect of waveform and its elimination are considered.

THE UNIVERSAL H.T. BATTERY ELIMINATOR.—N. P. Vincer-Minter. (*Wireless World*, 22, pp. 184 and 226, February, 1928.)

THIN-FILM RECTIFIERS.—J. Slepian. (*Electrical World*, 90, p. 1003.)

Abstract of paper presented before the American Electrochemical Society, September, 1927.

The principles underlying the operation of thermionic rectifiers are reviewed and applied to a theory of thin-film rectifiers. The phenomena exhibited by the following rectifiers are described and discussed in terms of this theory: crystal detectors, tantalum and ferro-silicon electrolytic rectifiers, electrolytic rectifiers with metallic conduction, the copper-hemi-sulphide rectifier of Pawlowki and the copper-oxide rectifier of Grondahl. The author contends that the many types of devices recently placed upon the market for rectifying 110-volt alternating current, etc., can be largely explained as due to the properties of thin-films separating two electrically conducting substances.

STEUERUNG VON ELEKTRONENSTRÖMEN IN QUECKSILBERDAMPFENTLADUNGEN (Control of electron currents in mercury vapour discharges.—E. Lübcke.) (*Zeitschr. f. techn. Physik*, 8, pp. 445–449, November, 1927.)

A paper presented at the meeting of German physicists at Bad Kissingen, September, 1927.

Description of the separation of the wall currents of a mercury vapour discharge into ions and electrons, leading to the construction of a new valve, by means of which anode currents up to 5 amps. can be obtained with anode tensions as low as 200 volts.

SUR LE DÉMULTIPLICATEUR DE FRÉQUENCE FERROMAGNÉTIQUE (The ferromagnetic frequency sub-multiplier.)—M. Rouelle. (*Comptes Rendus*, 185, pp. 1450–1452.)

THE MEASUREMENT OF ACOUSTIC IMPEDANCE AND THE ABSORPTION COEFFICIENT OF POROUS MATERIALS.—E. C. Wente and E. H. Bedell. (*Bell System Technical Journal*, 7, pp. 1–10, January, 1928.)

Various ways of determining the acoustic impedance and the absorption coefficient of porous materials from measurements on the standing waves in tubes are discussed, and values obtained for some commonly-used damping materials at different frequencies are given. The values for the absorption coefficients of a number of types of built-up structures are also tabulated, which show that relatively high absorption may be obtained at low as well as at high frequencies. The use of such combinations of absorbing materials has the advantage that more uniform damping at all frequencies can be obtained, and the degree of damping can be readily controlled by covering the proper area of surface. These two factors have become increasingly important in studio and auditorium design, with improved technique in recording and reproducing speech and music.

STATIONS: DESIGN AND OPERATION.

WORLD BROADCASTING: 1,116 STATIONS.—(*Electrical Review*, 6th January, 1928, p. 22.)

It is pointed out, in the *Telegraph and Telephone Age*, that radio telephone broadcasting services are now provided by 431 stations in 57 countries, in addition to the 685 operating in the United States and its non-contiguous territories. Outside the United States the most powerful broadcasting stations are those at Motala (Sweden) and Moscow (Russia), having 40,000 watts each; Russia also has a 29,000-watt station at Moscow, and one of 10,000 watts at Leningrad. Daventry operates on 16,000 watts. A station of power ranking above 40,000 watts is reported to be under construction in the Netherlands, while the Rosenhügel station, in Austria, is being transformed to a working capacity of 60 kW. and a nominal capacity of 200 kW.

THE DUTCH SHORT-WAVE STATION.—(*Wireless World*, 22, pp. 210–212, 29th February, 1928.)

Brief account of PCJJ, recently transferred from Eindhoven to Hilversum, with photographs of the equipment.

STATO ATTUALE DELLE STAZIONI TRASMITTENTI A ONDE LUNGHE (Present condition of long-wave transmitting stations.)—R. Hirsch. (*Radio-Tecnica*, 1, pp. 6–9, February, 1928.)

Although the attention of radio technical men, recently, has been mostly concerned with short-wave stations and broadcasting, the large companies still occupy themselves with perfecting the construction of ultra high-power long-wave stations. This article sets out the requirements of these stations, which ever become more exacting, and illustrates the extent to which they are being met by reference to the new high-power long-wave station of Torre Nuova, at Rome.

I MODERNI TRASMETTITORI AD ONDE CORTE PER SERVIZI COMMERCIALI (Up-to-date short-wave transmitters for commercial services).—M. Cabrini. (*Radio-Tecnica*, 1, pp. 21–27, February, 1928.)

An illustrated description of the Nauen station.

SIMULTANEOUS BROADCASTING IN CZECHO-SLOVAKIA.—E. K. Sandeman. (*Electrical Communication*, 6, pp. 171–177, January, 1928.)

Description of a typical example of the arrangements necessary for satisfactorily radiating a programme, originating at any one place, simultaneously from a number of transmitting stations.

GENERAL PHYSICAL ARTICLES.

THE RIGOROUS AND APPROXIMATE THEORIES OF ELECTRICAL TRANSMISSION ALONG WIRES).—J. R. Carson. (*Bell System Technical Journal*, 7, pp. 11–25, January, 1928.)

POTENTIAL DIFFERENCE AND CAPACITY IN A.C. PROBLEMS.—G. W. O. Howe. (*E.W. & W.E.*, 5, pp. 113-118, March, 1928.)

AN ELECTRICAL METHOD OF HARMONIC ANALYSIS.—S. Brown. (*Physical Review*, 31, p. 302, February, 1928.)

Abstract of a paper presented at the Nashville meeting of the American Physical Society, December, 1927.

MAGNETIC REFLECTION.—R. Abbott. (*Physical Review*, 31, p. 313, February, 1928.)

Description of an experiment proving the reflection of the magnetic field from a large electro-magnet by a zinc plate, which acted like a mirror due to eddy currents.

SIFFLEMENT CONTINU PRODUIT PAR UN QUARTZ PIÉZO-ÉLECTRIQUE ÉMETTANT SIMULTANÉMENT DEUX OSCILLATIONS DE HAUTE FRÉQUENCE (The continuous whistling produced by piezo-electric quartz simultaneously emitting two high-frequency oscillations).—F. Bedeau and J. de Mare. (*Comptes Rendus*, 185, pp. 1591-1593.)

THE HIGHLY PENETRATING COSMIC RAYS.—A. Corlin. (*Nature*, 3rd March, 1928, p. 322.)

A letter referring to the fact that Millikan and Cameron failed to detect variations in the intensity of cosmic rays (Supp. to *Nature* of 7th January), as found by Kolhörster, von Salis, Büttner and Steinke (after correcting his measurements for sidereal time) and giving reasons for suggesting the possibility that the variations are caused mainly by somewhat softer cosmic rays (coming from the "heated vacuum" of the Mira stars ?) than those found by Millikan and Cameron when their apparatus was sunk deep below the levels of the lakes used by them.

HIGH ALTITUDE TESTS ON THE GEOGRAPHICAL, DIRECTIONAL AND SPECTRAL DISTRIBUTION OF COSMIC RAYS.—R. Millikan and G. Cameron. (*Physical Review*, 31, pp. 163–173, February, 1928.)

THE DIFFRACTION OF ELECTRONS BY A CRYSTAL OF NICKEL.—C. J. Davisson. (*Bell System Technical Journal*, 7, pp. 90–105.)

Until the experiments described here were performed, it could be said that all experimental facts about the electron could be explained by regarding it as a particle of negative electricity; but now it appears that in some way a "wavelength" is connected with the electron's behaviour. The work thus shows an interesting contrast with the discovery of A. H. Compton that a ray of light (a light pulse) suffers a change of wavelength upon impact with an electron, a change corresponding exactly to the momentum gained by the electron.

Physics is thus faced with a double duality. Compton showed that light is in some sense *both* a wave motion and a stream of particles. The author now shows that a beam of electrons is in some sense *both* a stream of particles and a wave motion.

ON THE EXTRACTION OF ELECTRONS FROM COLD CONDUCTORS IN INTENSE ELECTRIC FIELDS.—O. W. Richardson. (*Proc. Roy. Soc.*, 117A, pp. 719–730, February, 1928.)

ON THE MECHANISM OF PHOTO-ELECTRIC EMISSION.—J. H. Hsu. (*Physical Review*, 31, p. 311, February, 1928.)

Abstract of a paper presented at the Nashville meeting of the American Physical Society, December, 1927, describing a simple theory of the mechanism of photo-electric emission, according to which the work function should in general be equal to the lowest resonance potential of the substance under investigation.

EVAPORATION OF TUNGSTEN UNDER VARIOUS PRESSURES OF ARGON.—G. Fonda. (*Physical Review*, 31, pp. 260-266, February, 1928.)

NOTE ON THE RÔLE OF POSITIVE IONS IN THE DISRUPTIVE DISCHARGE.—J. Townsend. (*Physical Review*, 31, p. 220, February, 1928.)

A UNIFIED THEORY OF GRAVITATION AND ELECTRICITY.—C. Snow. (*Physical Review*, 31, p. 150, January, 1928.)

Abstract of a paper presented at the Chicago meeting of the American Physical Society, November, 1927.

The theory gives the same advance of perihelion and bending of starlight by sun as Einstein's, but is mathematically distinct from his. Electric and magnetic (gravitational) charges are relative (like velocity) and physically indeterminate. They appear as projections of a charge-vector upon the time-like electrical axis and the space-like imaginary magnetic axis, which we may (and do) choose arbitrarily. Rotation of these axes in their plane would enable us to give an electron zero electric or zero magnetic charge, thus altering the form but not the content of our description of nature.

GRAVITATION AND ELECTRICITY AS MANIFESTATIONS OF A SIX-DIMENSIONAL WORLD.—C. Snow. (*Physical Review*, 31, p. 160, January, 1928.)

Abstract of a paper presented at the Chicago meeting of the American Physical Society, November, 1927.

SOME EXPERIMENTAL DIFFICULTIES WITH THE ELECTROMAGNETIC THEORY OF RADIATION.—A. H. Compton. (*Jour. Franklin Institute*, 205, pp. 155-178, February, 1928.)

NOTE ON THE LAW THAT LIGHT-RAYS ARE THE NULL GEODESICS OF A GRAVITATIONAL FIELD.—E. T. Whittaker. (*Proc. Cam. Phil. Soc.*, 24, pp. 32-34, January, 1928.)

MISCELLANEOUS.

TALKING AND SYNCHRONIZED MOTION PICTURES.—W. H. Bristol. (*Jour. Franklin Institute*, 205, pp. 179-196.)

A condensed presentation of the author's method of making and reproducing synchronized motion pictures.

PICTURES BY WIRELESS.—A. J. Smith. (*Electrician*, 13th January, 1928, pp. 27–28.)

Brief account of the development of the Telefunken-Karolus method in Germany.

WEIGHING BY RADIO.—(*Journ. Amer. Inst. E.E.*, 47, p. 16, January, 1928.)

A machine for automatically weighing material such as paper, rubber, has been developed in the laboratory of a New England producer of pulp and paper, the principles underlying the device being those of the tuned radio circuit. The web of material passes between two parallel metal plates which act as a condenser in the receiving circuit: variations in the weight of the web change the capacity of the condenser and affect the response of the circuit to a wave of controlled frequency. These variations are shown on a meter connected in the circuit and may be used to operate machine controls by suitable relays. The machine is of great service in maintaining uniformity in the weighing of paper and an adaptation of the device may be used to register the moisture content of the paper.

Über Verstärkung in der Bildtelegraphie (On amplification in picture telegraphy).—O. Schriever. (*Telefunken-Zeitung*, 47, pp. 78–84.)

Il Fonografo e la Riproduzione Elettrica (The phonograph and electric reproduction).—U. Guerra. (*Radio-Tecnica*, 1, pp. 10-16, February, 1928.)

The New Radio-Telegraph Convention.—Lieut.-Col. Chetwode Crawley. (*Electrical Review*, 24th February, 1928, pp. 322-323.)

Notes on the Convention drawn up by the International Conference held in the United States.

Laboratorien und Forschungsarbeiten der Funkabteilung der Deutschen Versuchsanstalt für Luftfahrt in Berlin-Adlershof (Laboratories and research work of the radio department of the German experimental establishment for aviation at Adlershof, Berlin).—H. Fassbender. (*Zeitschr. f. Hochfrequenz.*, 30, pp. 173-176, December, 1927.)

A brief description of the equipment and investigations carried out in the various sections, with illustrations.

D. E. H.

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPAGADO DE ONDOJ.

La Efekto de Veteraj Kondiĉoj ĉe Longdistanca Ricevado.—S. K. Lewer.

En ĉi tiu artikolo la aŭtoro skizas pluajn esploradojn pri la ĉi-supra temo (vidu *E.W. & W.E.*, Dec. 1925a kaj Julio 1926a). La mezuro de kondiĉoj por longdistanca, ekzemple, transatlantika, ricevado estas priskribita kiel C, kaj oni montras, per komparo de rezultoj, por 1924a, 1925a, kaj 1926a, ke ŝanĝoj ĉe C spertas specon de ĉiujara ripetado. Eblaj kaŭzoj por ĉi tiuj variadoj estas tiam diskutitaj, kaj diversaj fizikaj elementoj, kiuj kredeble havas tian influon, estas revuitaj. La aŭtoro poste diskutas variadojn de atmosfera premado kaj skizas konturajn mapojn de premado por unuj el la sendadaj vojoj. Kelkaj kondiĉoj, kiujn oni trovis bonaj kaj malbonaj respektive por sendado, estas montritaj, kaj rilato estas starigita inter prema distribuo kaj C.

La efekto de premaj ŝanĝoj je tera aŭ mara nivelo ĉe la premado kaj ionigado de la Tavolo Heaviside estas poste konsiderita, kaj la efekto de iu rezultanta kurbeco de la tavolo ĉe la refrakto aŭ reflekto de senfadenaj ondoj estas diskutita kaj ilustrita.

La aŭtoro konkludas, ke estas atestaĵo, ke la kondiĉoj por ricevado kaj la prema distribuado trans la Atlantika Oceano estas ripetitaj ĉiujare laŭ kompleksa sed difinita maniero, kaj ke estas rilato inter ili.

PROPRECOJ DE CIRKVITOJ.

Potenciala Diferenco kaj Kapacito ĉe Alternkurentaj Problemoj.

Redakcia artikolo de Prof. Howe kun gravaj aplikadoj al la teorio de antenoj.

La fundamentaj difinoj de potencialo kaj kapacito estas diskutitaj, kiel aplikita unue al kontinua kurento aŭ al elektrostatikaj problemoj. La malfacileco de ekzakta difino de potencialo en A.K. praktikado estas tiam pritraktita, kaj kelkaj aplikadoj estas ilustritaj kaj diskutitaj, notinde la mezurado de la potenciala diferenco inter diversaj partoj de a.k. senda linio. Per ĉi tio, modifo de la difino de potencialo kiel aplikita al a.k. estas derivita.

La argumento pri senda linio estas poste etendita al la ekzemplo de senda anteno. Oni konkludas, ke estas konsilinde ne provi ian a.k. difinon de la kapacito por unuo-longo de la anteno en la aplikado de la senda linia formularo, sed kalkuli la elektrostatikan kapaciton laŭ la supozo de distribuo de ŝarĝado, kiel ilustrita de l'aŭtoro. La induktanco por unuolongo estas poste konsiderita, kaj la aŭtoro konkludas, ke la metodo donas utilan proksimiĝon, uzante simplajn rimedojn por solvi tre kompleksan problemon.

Ĝeneraligita Teorio pri Antenoj.—R. M. Wilmotte.

La aŭtoro unue aludas al antaŭaj artikoloj de Colebrook kaj de Moullin, kaj al la malfacileco pri difinoj de la terminoj uzitaj je antenaj mezuradoj. Kapacito kaj induktanco por la unuo-longeco estas diskutitaj kaj la distribuo de la konstantoj en simpla vertikala anteno estas konsideritaj kaj ilustritaj. La efektivaj konstantoj de ricevaj kaj sendaj antenoj estas poste pritraktitaj, inkluzive la diferencoj, kiuj ekzistas en la du okazoj, la efektiva alteco, k.t.p. Oni priskribas eksperimentojn por kontroli la konkludojn atingitajn teorie, la ekzperimentoj ampleksantaj kaj ricevadon kaj sendadon. Utila metodo por trovi la naturan frekvencon de anteno estas ankaŭ donita, la metodo uzanta neniajn instrumentojn, kiuj eble, pro sia reaktanco, tuŝas la rezultojn.

Du matematikaj aldonaĵoj estas donitaj, la unua traktanta pri l'apartigo de reaktanco en ĝiajn kapacitan kaj induktancan konsistaĵojn, kaj la dua traktanta pri l'efektivaj konstantoj de l'antenoj dum sendado kaj ricevado.

Parazitaj Osciladoj en la Okazo de Agorditanoda Oscilatoro.—M. Reed.

La nuna artikolo estas daŭrigo de unu en *E.W. & W.E.* de Dec. 1927a, kiam la temo de parazitaj osciladoj estis pritraktita ĝenerale.

La okazo diskutita estas koncerne aŭdeblafrekvenca oscilatoro de 965 cikloj, kiam oni trovis diferencojn je la konduto laŭ la inversigo de kaj krada kaj anoda bobenoj kaj alĝustigo de la anoda konekta pinto.

La komuna induktanco uzita estas ilustrita, kaj eksperimentoj estas priskribitaj koncerne (1) La efekto de l'aŭdebla oscila cirkvito ĉe la parazita oscilado, (2) La forteco kaj frekvenco de la parazitaj osciladoj, (3) La efekto de kondensatoro konektita trans la anodo kaj krado, (4) Determino de la natura frekvenco de la konsisteroj de l'oscilatoro.

Eksperimentaj rezultoj estas donitaj por ĉi tiuj diversaj okazoj, el kiuj la parazitaj oscilaj cirkvitoj estas konsideritaj. La efektiva komuna induktanco inter la krada kaj anoda bobenoj, kun ambaŭ direktoj de konekto kaj por diversaj valoroj de anoda konekta pinto, estas konsideritaj, kaj klarigoj estas donitaj por la rezultoj obtenitaj en ĉi tiuj okazoj. La rilato inter la parazita oscilado, kaj la pozicio de la konekta pinto estas ankaŭ konsiderita.

Finiga resumo mallonge revuas la rezultojn, dum aldonaĵo traktas pri la determino de l'efektiva komuna indukto inter la anoda kaj krada bobenoj.

Bona Kvalito Ĉe Altfrekvencaj Amplifikatoroj.—C. C. Inglis.

La prelego traktas pri la larĝeco de strio necesa por esti pasigita de la altfrekvenca (ekz., agorditanoda) ŝtupo por bona kvalito.

Oni donas analizon de agordita cirkvito de L, R & C (Induktanco, Rezistanco, kaj Kapacito, respektive), kaj derivas esprimon por la larĝeco de strio (en cikloj ĉiusekunde) de la resonanca kurvo je $1/n^{ono}$ de ĝia alteco. Ĉe bona bobeno, oni montras ke por 5-procenta malaltigo el de la maksimumo, la stria larĝeco donita estus tro mallarĝa. La efekto de valva amortizo estas poste diskutita. Ĉe valvo de 20,000 omoj, oni montras, ke la efekto estus doni strion de bezonita larĝeco, sed valvo de 100,000 omoj (ekz., skrenita valvo) donus tro mallarĝan strion. Oni tial konkludas, ke valvo de tro alta impedanco devus ne esti uzita se bona kvalito estas konservota.

Du matematikaj aldonaĵoj estas donitaj.

HELPA APARATO.

Kio Estas la Korekta Karakterizo por Variebla Kondensatoro ?—Leŭt.-Kol. K. E. Edgworth.

La aŭtoro revuas la respektivajn meritojn de kondensatoroj laŭ la leĝoj (A) Rektlinia Kapacito, (B) Rektlinia Ondlongo, (C) Rektlinia Frekvenco. La argumentoj estas laŭ la duala vidpunkto de la bezonita interspaco inter stacioj kaj la facileco de korekta alĝustigo. Oni konkludas, ke la rektlinia ondlonga tipo estas feliĉa kompromiso posedanta la avantaĝojn (1) eviti amasigon de stacioj je mallongaj ondolongoj, kiel ĉe Rektliniaj Kapacitaj Kondensatoroj, (2) eviti tre krizan alĝustigon je longaj ondolongaj, kiel ĉe Rektliniaj Frekvencaj Kondensatoroj, (3) faciligi la konstruon de instrumentoj montrantaj ciferojn laŭ metroj.

DIVERSAĴOJ.

Resumoj kaj Aludoj.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato) kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

Libro-recenzoj.

Recenzoj estas donitaj pri la jenaj verkoj :

The Propagation of Radio Waves along the Surface of the Earth and in the Atmosphere. (La Propagado de Radio-Ondoj laŭlonge de la Surfaco de la Tero kaj en la Atmosfero) de P.O. Pedersen.

The Interaction of Pure Scientific Research and Electrical Engineering Practice. (La Interago de Pura Scienca Esplorado kaj Elektra Inĝeniera Praktikado) de Prof. J. A. Fleming.

A Study of Radio Direction Finding. Special Report No. 5 of the Radio Research Board. (Studo pri Radio-Direkto-Trovado. Speciala Raporto No. 5 de la Radio-Esplorada Komitato) de D-ro. R. L. Smith-Rose.

The Thermionic Valve. (La Termiona Valvo) de F. Goddard.

Les Filtres Electriques : L'Alimentation de Postes Recepteurs. (Elektraj Filtriloj : Provizado de Kurento por Riceviloj.) de M. Veaux.

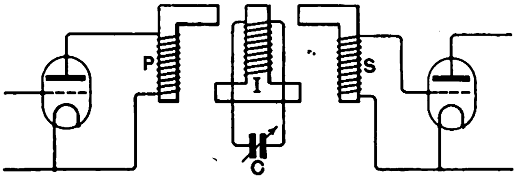
Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

SELECTIVE COUPLINGS.

(*Application date, 10th September, 1926. No.* 282136.)

A selective intervalve coupling comprises a primary winding *P* in the output circuit from the first valve, a secondary winding *S* connected to the grid of the second valve, and an intermediate winding *I*, tuned by means of a shunt condenser *C* to the desired signal frequency. Each coil is wound on separate cores built up of thin laminæ of high-grade annealed silicon steel, of a thickness of .002 to .003 inches and having high ohmic resistance and a very low hysteresis.



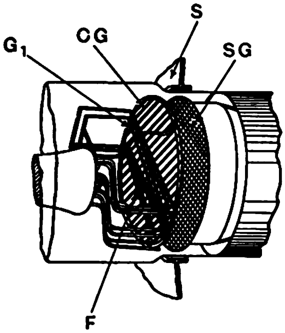
Frequencies other than that to which the intermediate coil is tuned are absorbed or dissipated in the metal-cored windings, though the desired signals are transferred through the coupling without appreciable loss.

Patent issued to the Dubilier Condenser Co., Ltd.

SHIELDED GRID VALVES.

(*Application date, 14th September, 1926. No.* 282150.)

The introduction of a positively-charged auxiliary grid between the control grid and the filament, although it serves the desired purpose of neutralising the space charge, has the disadvantage that it tends to absorb considerable quantities of current. In order to obviate this drawback the inventor proposes to use a space-charge grid constructed of a very fine single wire running parallel to the filament and located between the latter and the control grid.



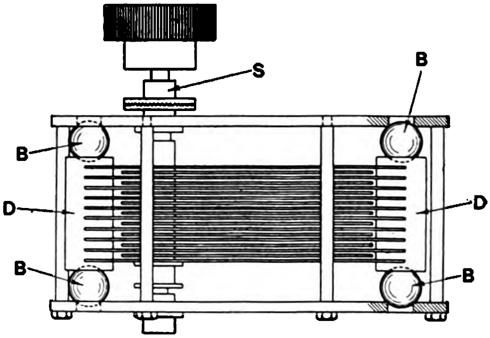
The invention is illustrated as applied to a shielded-grid valve of the Round type, comprising a *W*-shaped filament *F*, a control grid *CG*, and a shielding grid *SG* co-operating with an external screen *S*. The additional space-charge grid G_1 is shown mounted parallel with and just above the filament *F*. It is preferably made of the same gauge wire as the filament.

Patent issued to H. J. Round.

TUNING CONDENSERS.

(*Convention date (Austria), 25th January, 1927. No.* 282580.)

In order to facilitate the assembly of variable condensers, loose glass balls *B* are used as shown so that the parts can be centred rapidly and automatically. The moving plates are secured to a control spindle *S* as usual. The fixed plates are first mounted in blocks *D* which are then clamped by means of screw bolts against the insulator balls *B*, seated in suitable slots or depressions, as shown.



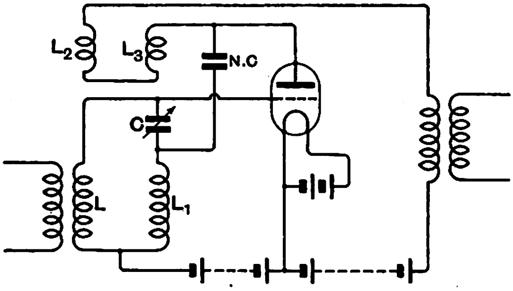
Patent issued to F. Horny.

PARASITIC OSCILLATIONS.

(*Convention date (U.S.A.), 17th July, 1926. No.* 274472.)

It is pointed out that when attempts are made to neutralise interelectrode capacity effects by the well-known method of using a small feed-back condenser between the plate and a central tapping on the input coil, parasitic or ultra high-frequency oscillations are liable to be set up, particularly where several stages of balanced high-frequency amplification are connected in series. A remedy is found by introducing a definite inductive coupling between the plate and grid, the sense in which the coupling coil is wound being such as to oppose regeneration at the parasitic frequency.

For instance the coils L, L_1 are equivalent to the centrally-tapped input coil used in the original Rice circuit, the neutralising condenser being shown at *NC*, and the tuning condenser at *C*. The extra stabilising coils are shown at L_2 and L_3,



and are coupled respectively to the coils L and L_1. In practice the windings L, L_1 are combined into one coil, whilst the coils L_2, L_3 are similarly united, so that the resultant or overall back-coupling effect is substantially zero and does not diminish the signal strength.

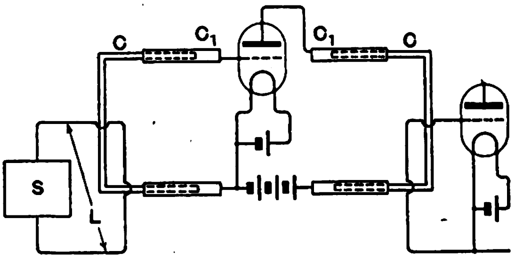
Patent issued to The Westinghouse Electric Co.

HANDLING ULTRA HIGH FREQUENCIES.

(*Application date*, 15*th October*, 1926. *No*. 283651.)

In order to avoid undesirable capacity leakage, and to keep circuit induction within the necessary limits in generating and amplifying very short wavelengths, the input and output leads of the generating or amplifying valves are constructed in the form of telescopic "wave" circuits as shown. A wave circuit is defined to be one in which the conductors are of a length comparable with that of the waves being handled.

In the case of the amplifier shown, the input voltage from a source *S* is applied to the system by magnetic coupling between the leads *C* and *L*. A corresponding electro-magnetic wave is set up in the space between the upper and lower pair of conductors, *C*, C_1, and travels with approximately the speed of light towards the grid of the amplifier,



where it is reflected back again, and so on. The optimum disposition of the voltage loops and nodes of the stationary-wave system to set up is secured by adjusting the overall length of the telescopic lead *C*, C_1.

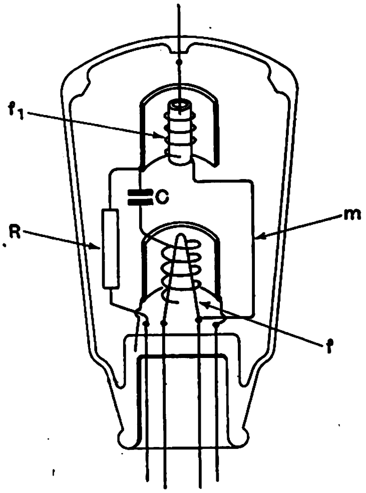
Patent issued to Standard Telephones & Cables.

A PHOTO-ELECTRIC VALVE AMPLIFIER.

(*Convention date* (*Germany*), 12*th November*, 1925. *No*. 261391.)

The electron-emission required in the first valve stages of a multi-valve receiver is only a small fraction of that expended in the last or power-amplifying valve, where a considerable current must be made available in order to drive the loud-speaker. Dr. Loewe utilises this fact to secure a welcome reduction in expenditure of filament current by depending upon the light and heat energy radiated from the incandescent filament of the power stage to liberate a sufficient supply of electrons to run one or more of the earlier valves.

Fig. 1 shows a multiple-unit valve containing two separate sets of electrodes. The lower or power-amplifying set comprises a filament *f* heated by a battery as usual, a spiral grid, and cylindrical plate. The upper set consists of a "cold" cathode f_1, preferably a cylinder coated with photo-electric substance such as sulphite of thallium, or a hydride of selenium or rubidium, which liberates electrons under the influence of the light and heat radiated from the incandescent filament *f*. The electron emission from the upper cathode may also be supplemented by a direct metallic connection *m*. The intervalve coupling consists of a special high-resistance element *R* and a condenser *C*.



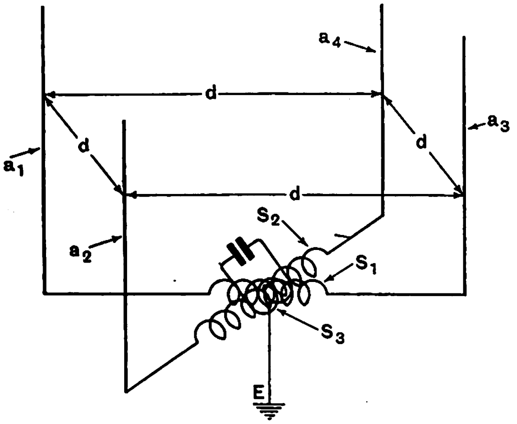
Patent issued to Dr. Siegmund Loewe.

DIRECTION-FINDING.

(*Convention date* (*Germany*), 29*th October*, 1926. *No*. 279794.)

It is found that the accuracy of the readings given by the standard *DF* equipment, particularly in the case of aircraft flying at a considerable height above the ground, largely depends upon the elevation at the moment of taking the bearings, and also upon the polarisation of the incident ray. A vertically-polarised ray will, for instance, give a very different result to one that is horizontally polarised.

Variable readings due to such changes of polarisation are avoided by using a receiving aerial of the form shown in the Figure, and comprising four vertical wires a_1, a_2, a_3, a_4, each individually non-directional and connected diagonally in pairs through coils S_1, S_2, the centres of which are earthed at E. The coils S_1, S_2 are in turn coupled to the pick-up or search coil S_3 leading to the bearing dial. The distance d between the wires must be not greater than one-tenth that of the working wave-length for satisfactory results. The derivation of this distance factor is set out mathematically in the specification.

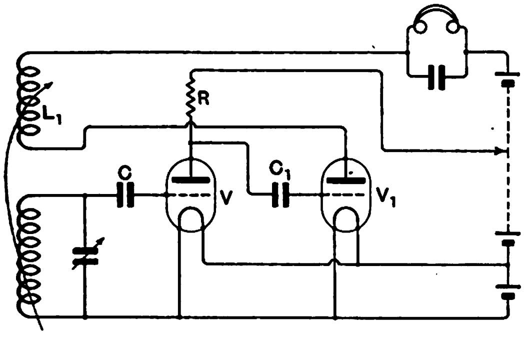


Patent issued to Dr. A. Esau.

REGENERATIVE RESISTANCE COUPLINGS.

(*Application date*, 19th *October*, 1926. *No.* 284002.)

When an anode-bend rectifier V is resistance-coupled to a following valve V_1, it is well known that the best results can be obtained by using a high value of coupling resistance, but it is then difficult to introduce reaction. The drawing illustrates a circuit whereby this difficulty can be overcome.



A condenser C of 0.001 mfds is inserted in the grid lead of the first valve. This ensures that the grid potential is automatically adjusted to the strength of the incoming signals, thus avoiding the necessity for using a potentiometer. A condenser C_1 of 0.002 mfds is also inserted in the grid circuit of the valve V_1. No leak resistance is used in either case. The absence of a grid leak across C_1 is stated to reduce the internal impedance of the valve V_1, thereby facilitating the introduction of reaction, through the medium of a coil L_1.

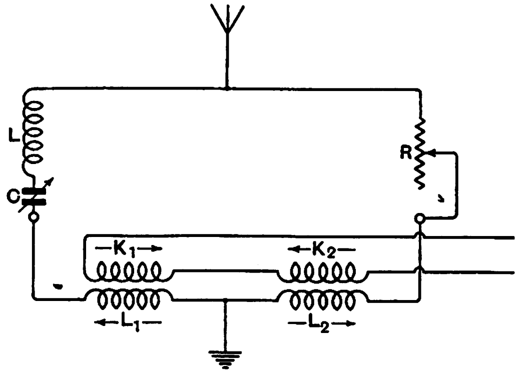
On the longer wavelengths the sense of reaction usually reverses, and for this work it is preferred to use capacity reaction in the form of a small condenser of 0.002 mfds inserted between the plate of valve V_1 and the grid of valve V, a high-frequency choke being placed on the plate circuit of the second valve.

Patent issued to C. E. Prince and W. S. Percival.

INTERFERENCE-ELIMINATORS.

(*Convention date* (*Germany*), 3*rd February*, 1926. *No.* 271911.)

In order to cut out interference due to a particular undesired frequency, the receiving aerial is branched into two circuits, each containing a similar loading coil L_1, L_2 to which the pick-up coils K_1, K_2 feeding the receiver are coupled. The left-hand branch circuit comprises an additional inductance L and capacity C tuned to the interfering wave-length, so that it forms an acceptor circuit for that particular signal.



Under these circumstances the circuit LC presents zero impedance to the undesired signals, so that the corresponding induced currents can be perfectly balanced by means of a resistance R inserted in the right-hand branch of the aerial, no phase compensating means being required. The direction of the primary and secondary currents due to the undesired signals are indicated by the arrows, from which it will be seen that they are balanced out so far as the receiver circuit is concerned.

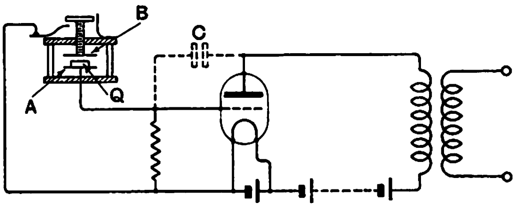
Incoming signals of any other frequency will not however be eliminated, but will pass through to the receiver, though at slightly reduced strength. The arrangement is stated to be particularly useful for combined receiving and transmitting sets, the receiver being completely shielded from the effects of the local transmitter. The method can also be adapted for eliminating several disturbing wave-lengths by adding other aerial branches containing suitable acceptor circuits.

Patent issued to the C. Lorenz Co.

PIEZO-ELECTRIC CONTROL.

(*Application date, 2nd November,* 1926. *No.* 284761.)

The generation frequency of an oscillating valve is controlled by adjusting the thickness of the air-gap between a piezo-electric crystal and one of its plate electrodes. The Figure shows a valve sustained in continuous oscillation through inter-electrode capacity, indicated by the condenser *C* shown in dotted lines. The grid of the valve is connected to the lower support or electrode *A* of a quartz crystal *Q*, whilst the filament is connected through a terminal to an adjustable screw carrying the upper crystal electrode *B*.



As the air-gap between the plate *B* and crystal *Q* is increased, the oscillation frequency of the valve rises until a point is reached when the crystal ceases to vibrate. Conversely as the air gap is diminished the valve frequency decreases.

The crystal may be considered to act as a capacity reactance at all frequencies except at a resonant frequency, when its reactance may be either capacitative or inductive. In order to sustain the valve in oscillation, when the back-coupling between plate and grid is capacitative, as shown, the effective reactance both in the plate and grid circuits must be inductive. Accordingly by varying the reactance in the output circuit of the valve, the latter may be set so as to oscillate at any one of the fundamental or resonance frequencies peculiar to the crystal *Q*.

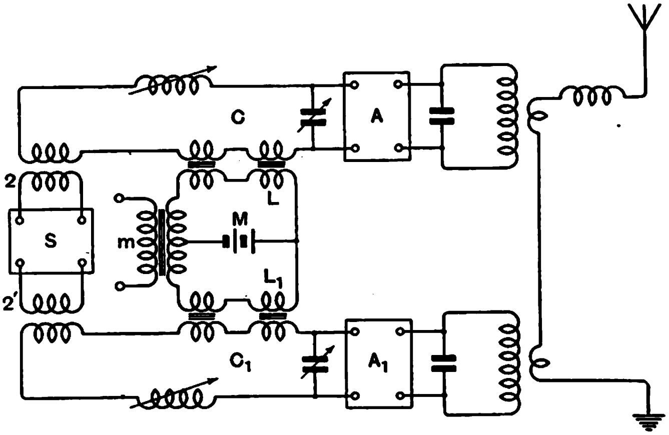
Patent issued to Standard Telephones & Cables, Ltd.

MODULATION BY PHASE-DISPLACEMENT.

(*Convention date* (*France*), *10th May,* 1926. *No.* 270749.)

Signalling is effected by altering the relative phases of two carrier-waves of the same frequency, the arrangement being such that for ordinary Morsing the difference in phase varies directly with the amplitude of the signals, and at signal frequency, whilst in speech or other modulated signalling the phase-difference varies directly with the amplitudes of the acoustic currents. In this way sufficient modulation is secured with a comparatively low power-expenditure, the modulated high-frequency currents being subsequently amplified. There need be no amplitude change, but only a phase variation, at the receiving end, and in this form the system provides an effective method of secret signalling, since the ordinary type of receiver will not detect the modulation.

The simplest type of circuit, in which the phase variations create changes of amplitude in the received wave, is shown in Fig. 1. High-frequency oscillations from a source *S* are fed through windings 2, 2^1, arranged to have a phase-displacement of say 150 degrees, to two circuits *C*, C_1. The latter are coupled to a magnetic modulator *M* in which the signal currents from a source *m* tend to increase the saturating current say in the coils *L* and reduce it in coils L_1, thus setting up the required phase-variation in the currents flowing in the circuits *C*, C_1. These are subsequently passed through separate amplifiers *A*, A_1 and combine vectorially in the transmitting aerial.



Patent issued to Soc. Française Radio-Electrique.

EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. V. MAY, 1928. No. 56.

Editorials.

Symbolical Algebra.

IN an editorial note in our issue of May 1927 we commented on a letter from Mr. W. A. Barclay, which appeared in the same issue dealing with the subject of $\sqrt{-1}$ and the Heaviside operator. In the present issue we publish an article on "Symbolical Algebra," by Mr. J. A. Ratcliffe, B.A., of Cambridge, in which he develops the subject step by step in the orthodox way and shows that, if properly employed, there is no need to distinguish between $j = \sqrt{-1}$ and j, the so-called vector operator. No one can doubt the truth of his concluding remark that "provided sufficient care is taken in the interpretation of the results, this symbolical algebra is a very powerful weapon in the hands of the mathematician." There are difficulties, however, which do not seem to have occurred to Mr. Ratcliffe. Our editorial of a year ago was prompted by Mr. Barclay's suggestion to do away with j as a vector operator and replace it by D/ω, and we considered therefore three symbols, standing for three distinct ideas, viz., D/ω, j as an operator, and $\sqrt{-1}$. Nobody will deny that these symbols stand for three entirely different conceptions; the first, rate of change divided by cyclic frequency; the second, rotation of a vector through 90 degrees; the third, an imaginary arithmetical process. If this be granted, then it follows that any such statement or assumption as $D/\omega = j = \sqrt{-1}$ should be treated with suspicion. Mr. Barclay's letter dealt mainly with the first pair, as he wished to have nothing to do with $\sqrt{-1}$; Mr. Ratcliffe's article ignores D/ω, but strongly supports $j = \sqrt{-1}$. Mr. Barclay claimed an enormous simplification by the use of the D/ω notation, but we showed not only the impossibility of treating the operator D/ω as an algebraic multiplier, as is obvious from the fact that $(D \sin \omega t)^2$ is not the same as $D^2 \sin^2 \omega t$, but also the fallacy of assuming that because the effect of two similar operations carried out successively is represented by a certain symbol, viz., -1, it necessarily follows that a single operation is correctly represented by the square root of this symbol.

Mr. Ratcliffe does not appear to appreciate the difficulties connected with j. He defines it as $\sqrt{-1}$ and then proceeds to find a geometrical interpretation of it. But this is merely giving it another definition. Because multiplication twice in succession by $\sqrt{-1}$ is equivalent to a change of sign, it is not *natural* but very *artificial* to assume that a single application—he wisely avoids saying "multiplication" at this point—to a magnitude will rotate it through 90 degrees. Later he is less precise and says that "multiplication of the rotating vector e^{jpt} by j will give another rotating vector

90 degrees ahead"; surely "orientation" would be a better word than "multiplication" to describe such a process.

Mr. Ratcliffe concludes with the hope that "it will be clear that j means exactly the same when used in purely algebraical work and when used in symbolical algebra, and that there is no distinction between $j = \sqrt{-1}$ and j, the so-called vector operator." In our opinion they mean very different things, and there is a very great distinction between them. The square root of a minus quantity is an arithmetical fiction which we call an imaginary quantity—although this is hardly fair to the imagination—whereas the operation of rotating a line through 90 degrees is a simple thing that a child can not only comprehend but actually do. One must surely be hypnotised by the unquestioned beauty and utility of symbolical algebra to suggest that there is no distinction between two such utterly different things. We leave our readers to judge of the correctness of the statement that the square root of a minus number, although called an imaginary number, "is not, in the everyday sense of the word, any less real than is the ordinary number."

The Self-induction of Single-turn Circuits of Various Shapes.

In connection with Mr. Allen's article on formulæ for the self-induction of single-turn circuits of various shapes which we publish in this issue, we would draw our readers' attention to an article on the same subject by M. Bashenoff, the chief of the wireless section of the Soviet Research Institute at Moscow, published in the December issue of the Proceedings of the Institute of Radio Engineers. The inductances of various single-turn circuits are expressed in terms of their perimeters, that is, of the length of wire l, its radius r, permeability μ, and a correction factor δ depending on the frequency f which, of course, only modifies the flux within the material of the wire itself; $\delta = 0.25$ for D.C. and low frequencies and decreases as the frequency increases.

The results are all expressed in the convenient form

$$L = 2l\,(\log_e \frac{2l}{r} - \alpha + \mu\delta)$$

where α has the following values:

Circle ..	2.451	Square	2.853
Octagon.	2.561	Equilateral triangle	3.197
Hexagon	2.636	Isosceles right-angle triangle	3.332
Pentagon	2.712		

If $x = 0.281\ r\sqrt{\mu f/\rho}$, where ρ is the specific resistance of the wire in microhms per cm.-cube, then δ depends on x in the following way:

$x =$	0	1	2	5	10	20	40	70
$\delta =$	0.25	0.25	0.24	0.14	0.07	0.035	0.018	0.010

G. W. O. H.

Symbolical Algebra.

By J. A. Ratcliffe, M.A.

THIS article draws attention to some mistakes which are often made in applying the processes of symbolical algebra to the treatment of problems containing sine and cosine functions. In the edition of this periodical for May, 1926, there appeared an editorial and a letter from Mr. W. A. Barclay, as a result of which it might be thought that the j which appears in the operational equations is something quite different from the j of ordinary algebra, and does not obey the same algebraical laws. In this article we shall show that, if the problem is looked at in a slightly different way, this apparent difference disappears, with the result that the method of symbolical algebra becomes much more useful than it is if we have continually to remember whether the j which we use has its algebraical or its operational significance.

In symbolical algebra we try to attach some physical or geometrical meaning to an algebraical symbol (such, for example, as $j = \sqrt{-1}$). We then apply the ordinary rules of algebra to this symbol, and so deduce more complicated expressions, and these expressions may then be interpreted directly in terms of their geometrical or physical meaning. It is essential that, once a geometrical statement has been put into an algebraical form, we should be able to apply all the ordinary operations of algebra to the expression, *without any thought as to the geometrical meaning of the symbols*. The resulting equation can then be interpreted, according to the rules which we will lay down, and will give a result which is known to be true from a geometrical standpoint. From the treatment given in the Editorial previously referred to, it would appear that this is not the case, but that we must always bear in mind the geometrical meaning of the operator, and only perform on it such algebraical operations as do not violate the geometrical laws. If this were the case the method would lose all its use and beauty, but we shall show that the treatment previously referred to was incorrect and if the idea of the symbolical operator is correctly applied it gives a very powerful method for the algebraical solution of Physical and Geometrical problems involving circular functions (sines and cosines).

Let us define j by means of the *algebraical* equation $j = \sqrt{-1}$. As a result of this we see that $j^2 = -1$. Now it is obvious that there is no ordinary number whose square is equal to -1, and so we call j an *imaginary* number. It must be clearly understood that the term "imaginary" is merely a name to distinguish this kind of number from the more usual kind. An imaginary number is not, in the every-day sense of the word, any less real than is the ordinary number. Having now defined j in an algebraical manner, we may work with it just as we would with any other symbol and we may apply all the ordinary operations of algebra to it.

Suppose we have a number made up of the sum of an ordinary number and an imaginary number, such, for example, as $x + jy$; we call this a *complex number* and say that it consists of a real part x and an imaginary part jy. If two complex numbers are equal to each other, then their real parts are separately equal and their imaginary parts are also equal. Thus if $x+jy = a+jb$ then $x = a$ and $y = b$. This is easily seen by transposing the equation thus $(x - a) = j(b - y)$, *i.e.*, a real number is equal to an imaginary, which cannot be true, unless both $x - a = 0$ and $b - y = 0$; which gives $x = a$ and $y = b$. Thus, if our algebraical work leads to an equation in which one complex number is equal to another, then we may equate the real part of the one side to the real part of the other side, and the imaginary part of one side to the imaginary part of the other and so obtain two independent equations from the one.

Having defined j algebraically, let us now look for its geometrical symbolical meaning. From the equation $j^2 = -1$ we see that j is a symbol which, when applied twice to a magnitude, converts it into a negative magnitude of the same size. In geometry, this is equivalent to rotating the line which represents the magnitude, through 180°. Hence applying the symbol to a magnitude twice in succession will rotate it through 180°, and so it is natural to suppose that applying the symbol j to a magnitude once will rotate it through 90°. It is important to notice that this is only a geometrical *interpretation* of the symbol j and that it is still *defined* by the equation $j = \sqrt{-1}$.

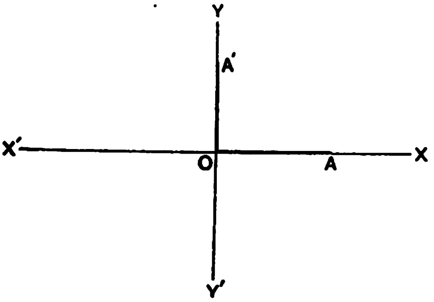


Fig. 1

Now suppose that all positive real numbers are represented by lines of corresponding length drawn along OX. Then the number a is represented by the line OA (Fig. 1). The number ja must be represented by a line of length "a" in a direction perpendicular to OA, that is, it is represented by OA'. Now since the quantities OA and OA' have magnitude and direction they are of the kind called vectors. If we wish to add such quantities we must employ the parallelogram law for vector addition, which says that the sum of two vectors OA and OB (Fig. 2) is the vector represented by the diagonal OB of the parallelogram having OA and AB as adjacent sides. Geometrically, this means that going a distance OA along OX and then a distance AB perpendicular to OX leads us to the same point as going a distance OB along the direction of OB. Thus we may say $\overline{OA} + \overline{AB} = \overline{OB}$ (a bar over a symbol is used to denote that it represents a vector quantity). If we express this in terms of symbols it becomes $a + jb = Z$. The quantity Z is a complex number and represents the vector $\overline{OB}$. Thus a real number corresponds to a vector along OX, an imaginary number to a vector along OY, and a complex number to a vector in any intermediate position. It is easy to see that the complex vector $a + jb$ $(\overline{OB})$ has actual length given by $\sqrt{a^2 + b^2}$ and makes an angle with OX given by $\tan \theta = b/a$.

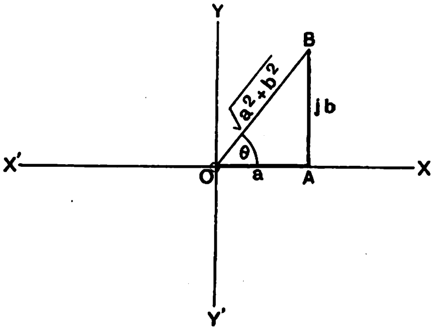


Fig. 2

We are now in a position to work out a simple problem by means of symbolical algebra. Let us rotate the vector represented by $a + jb$ through 90°. By the processes of symbolical algebra we have merely to multiply it by j. This gives

$$j\,(a + jb) = -\,b + ja.$$

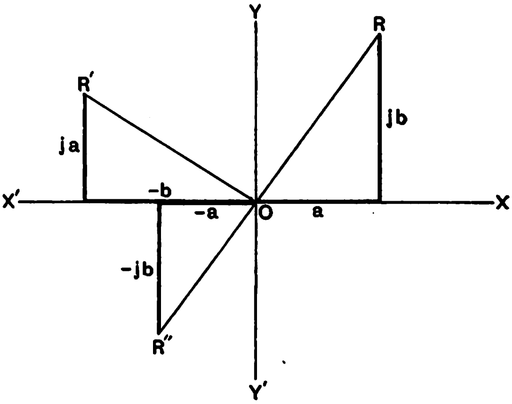


Fig. 3

If, now, we go back to the geometrical meaning of this, it indicates that we must go a distance b along the negative direction of OX (Fig. 3) and a distance "a" perpendicular to OX. This leads to the point R' and it is easily seen that OR and OR' are mutually perpendicular. Thus multiplication of a complex number by j always corresponds to rotation of the corresponding vector through a right angle. If we wish to rotate the vector OR' through a further 90° we must multiply $a + jb$ by a further j, and we obtain $j\,(-\,b + ja) = -\,a - jb$, which gives us at once the vector OR'' and we see that OR has now been rotated through 180°.

Now let us consider what is meant by the expression $a \sin pt$. Algebraically it is a real number which varies in a simple harmonic manner between the values $+ a$ and $- a$, the time period being $2\pi/p$. Since, algebraically, it is a real number, then we interpret it geometrically as a line drawn along OX, whose length varies periodically with period $2\pi/p$; the end of this line moves, in fact, with simple harmonic motion. Let us now enquire what is the geometrical interpretation of the algebraical expression $ja \sin pt$. Since it is an imaginary number, it represents a line drawn along OY. It is also periodic, and so represents a simple harmonic motion along OY. The simple harmonic motion (S.H.M.) along OX (represented by $a \sin pt$) and the S.H.M. along OY ($ja \sin pt$) are in phase with each other. The multiplication by j has simply *turned the S.H.M. through* 90° *in space.* There is no change of phase, and $\cos pt$ does not appear in the equations at all. There is no reason, either algebraical or geometrical, for supposing that j represents differentiation or for writing

$$\frac{d}{dt}\sin pt = jp \sin pt$$

as is often done, and in fact this statement is quite untrue.

We see from this that the use of the symbolical operator j does not help us very much so far. By making a further extension, however, we arrive at a symbolical method which is very useful in A.C. circuit problems.

Let us consider the complex number $a\,(\cos pt + j \sin pt)$. From the exponential definitions of sine and cosine we see that this is equal to e^{ipt} as is shown below:

$$\left.\begin{aligned} \cos pt &= \frac{e^{jpt} + e^{-jpt}}{2} \\ j \sin pt &= j\frac{e^{jpt} - e^{-jpt}}{2j} \end{aligned}\right\} \therefore \begin{aligned} &\cos pt \\ &\quad + j \sin pt = e^{jpt} \end{aligned}$$

It is important to notice that this equality holds because j has been defined algebraically by the equation $j = \sqrt{-1}$. The geometrical interpretation of the complex number $a\,(\cos pt + j \sin pt)$ (or ae^{jpt}) is as follows. It is a vector, whose absolute length is given by $a\sqrt{\cos^2 pt + \sin^2 pt} = a$, and which makes an angle θ with OX such that

$$\tan\theta = \frac{\sin pt}{\cos pt} = \tan pt,$$

and hence $\theta = pt$. Thus as the time t increases the angle steadily increases, and so the vector continually rotates, the angular velocity being p. We therefore see that ae^{jpt} represents a vector of constant magnitude a, which rotates with constant angular velocity p. Its end will trace out a circle at a constant speed. If now we take the projection of this rotating vector on the x axis we shall, by the ordinary definition of S.H.M., arrive at the periodically changing vector represented by $a \cos pt$. We arrive at the same result, algebraically, by taking the real part of the complex number $ae^{jpt}[= a\,(\cos pt + j \sin pt)]$. We may write this $R[e^{jpt}] = \cos pt$, which means that the real part of e^{jpt} is $\cos pt$. The mistake is often made of writing $e^{jpt} = \cos pt$, which is quite untrue and leads at once to difficulties. We can see the nature of these difficulties by the following example. Let us enquire what is meant by $\{e^{ipt}\}^2$. We have the following algebraical equations:

$$\begin{aligned} \{e^{jpt}\}^2 &= e^{2jpt} = \cos 2\,pt + j \sin 2\,pt \\ \text{and } \{e^{jpt}\}^2 &= \{\cos pt + j \sin pt\}^2 \\ &= \cos^2 pt - \sin^2 pt + 2j \cos pt \sin pt \\ &= \cos 2p + j \sin 2\,pt. \end{aligned}$$

Thus we see that we obtain the same result by squaring the expression e^{jpt} and then proceeding to its interpretation in terms of sines and cosines, or by interpreting it first in terms of sines and cosines and then squaring it. If, however, we restrict ourselves to the real parts of these expressions we obtain the equations

$$\begin{aligned} e^{jpt} &= \cos pt. \\ \{e^{jpt}\}^2 &= \cos^2 pt = e^{2\,jpt} = \cos 2pt \end{aligned}$$

which is obviously wrong. We should have written $R\,e^{jpt} = \cos\ pt$, and then we should have

$$R[\{e^{jpt}\}^2] = R[e^{2jpt}] = \cos 2pt$$

which we have seen to be true.

Let us now proceed further, and apply the process of differentiation to the complex number e^{jpt}. We have

$$\frac{d}{dt}e^{jpt} = jpe^{jpt}.$$

Thus differentiation of e^{jpt} is equivalent to multiplication by jp. It would be quite wrong to say that differentiation of the real part of e^{jpt} was also equivalent to multiplying by jp, which is done if we write

$$\frac{d}{dt}\cos pt = jp \cos pt \qquad \text{.. (1)}$$

We have seen that differentiation of e^{jpt} is equivalent to multiplication by jp. Let us enquire into the geometrical interpretation of this. Multiplication of the rotating vector e^{jpt} by j will give another rotating vector 90° ahead of the original one, and multiplication by p will increase its size p times. Projection of this new vector on the x axis will give the S.H.M. $p \cos (pt + \pi/2)$, which is 90° out of phase with the original S.H.M. and has amplitude p times as large. The new S.H.M. can also be represented as $-p \sin pt$. We could have deduced this algebraically from the equation

$$\frac{d}{dt} e^{jpt} = jpe^{jpt} \text{ or } \frac{d}{dt}(\cos pt + j \sin pt) = jp (\cos pt + j \sin pt)$$

by taking the real parts of both sides, when we obtain

$$\frac{d}{dt} \cos pt = -p \sin pt \quad \ldots \quad \ldots \quad (2)$$

It is important to notice the difference between the process employed here and the process employed in deducing the fallacious equation (1). In the first case we took the real parts of both sides and then differentiated, while in the latter we have differentiated and then taken the real parts. We may express these two processes as follows

$$\frac{d}{dt} R[e^{jpt}] = jpR[e^{jpt}] \qquad \text{INCORRECT} \quad (1a)$$

$$R[\frac{d}{dt} e^{jpt}] = R[jpe^{jpt}] \qquad \text{CORRECT} \quad (2a)$$

The results of this argument are as follows. We define j algebraically, and as a result we can work with it just as we should with any other quantity, and our results are always correct algebraically. [Such a result as $j \sin pt = \cos pt$, which was given in the editorial referred to, is algebraically quite untrue.] We then find a geometrical interpretation of the symbol j, by means of which we can always pass from any true algebraical equation to a corresponding geometrical statement. It is hoped that it will be clear that j means exactly the same when used in purely algebraical work and when used in symbolical algebra, and that (contrary to what is said at the end of the previous editorial) there is no distinction between $j = \sqrt{-1}$ and j, the so-called vector operator.

The Reflecting Layer of the Upper Atmosphere.

An Estimation of the Height for Wireless Waves of 600 Metres Wavelength in New Zealand.

By G. H. Munro, M.Sc.

DURING December, 1925, a series of special signals was transmitted from Wellington wireless station for the purpose of making direction-finding observations at a receiving station near Auckland, a distance of approximately 300 miles. The signals consisted of spark transmission on 600 metres for 5-minute periods with intervals of 5 minutes, from 3.30 to 4.30, sunrise at Auckland then being at about 4.25 a.m., and were observed on 21 days from the 7th to the 31st December. The average intensity during each period was estimated aurally and recorded, allowance being made for rapid fading due to "night effect."

It was found that the rate of decrease in the strength of normal signals varied in much the same way each day. The observations for 21 days were therefore tabulated, a scale of numerical values assigned to the strengths as recorded, and an average strength for each period derived. This tabulation is given below.

The figures in the columns represent strengths ranging from 6, the maximum night strength, to 1, the normal daylight strength.

The time of sunrise varied, of course, during the month, being at 4.25 a.m. on the 7th, 4.26 on the 16th, 4.29 on the 24th, and 4.33 a.m. on the 30th and 31st; but, considering the degree of accuracy obtainable, it was considered sufficient to take the average value of 4.27½ a.m. The difference between this and the middle of the period of observation was then taken as the time before sunrise, of the observation. These are the figures given at the top of the tabulation.

It is seen that until 45 minutes before sunrise the decrease in strength is small. During the next two 10-minute periods there is a considerable decrease, at a rate increasing with time. From 25 minutes before sunrise to 15 minutes before, the decrease is very great, the rate being then a maximum. After this the rate of decrease rapidly becomes less, as the strength is now reduced almost to the normal daylight strength.

It should be noted that the figures serve mainly to enable averages to be computed, and while they indicate the relative strengths, they are probably not indicative of the actual current-strength of the received signals.

EFFECT OF SUNLIGHT ON SIGNAL STRENGTH.

Date.	Average Time of Observation before Sunrise, in Minutes.						
December.	55.	45.	35.	25.	15.	5.	− 5.
7	5	3	3	2	1	1	1
8	6	5	5	5	3	2	2
9	5	5	4	3	2	2	2
10	6	6	6	5	4	2	2
11	6	6	6	5	2	2	1
12	5	3	3	2	3	3	3
—							
14	6	6	5	4	3	2	1
15	6	6	4	2	3	1	1
16	6	6	6	6	3	2	2
17	6	4	3	3	3	3	1
18	6	6	6	6	3	2	1
19	6	5	5	4	2	1	1
—							
21	6	6	5	5	3	2	2
22	4	5	3	3	2	1	2
23	6	6	6	3	2	2	2
24	6	6	5	3	1	1	1
—							
26	6	6	5	4	3	2	2
—							
28	5	4	3	3	3	1	1
29	4	5	4	4	3	2	2
30	4	5	3	4	1	1	2
31	2	5	4	1	1	2	2
Total 21	112	109	94	77	51	37	34
Average	5.36	5.19	4.47	3.66	2.43	1.76	1.62

These results are interesting when considered with respect to the least height at which the sun is shining in the path of the received rays. Assuming a single reflection of the waves, it will occur approximately vertically over a point mid-way between the transmitting and receiving stations. The height of the sunlight above this point can be calculated from a knowledge of the time of sunrise at that point, its latitude, and the time of the year. As the degree of accuracy is not great, a mean time of sunrise for the month may be taken, and the calculations made as at midsummer in the southern hemisphere. The values found for the conditions of the observations are given below:

Minutes before sunrise at receiving station	55	45	35	25	15
Height of sunlight in miles at point mid-way between stations	57	36	19	8	1

Since there is little effect in the first period, the corresponding height (*i.e.*, 57 miles) should be that of the lower boundary for the Heaviside layer.

The heights at which the sun was shining at the particular times were calculated by trigonometry. In case the method should be of interest, it is added as an appendix.

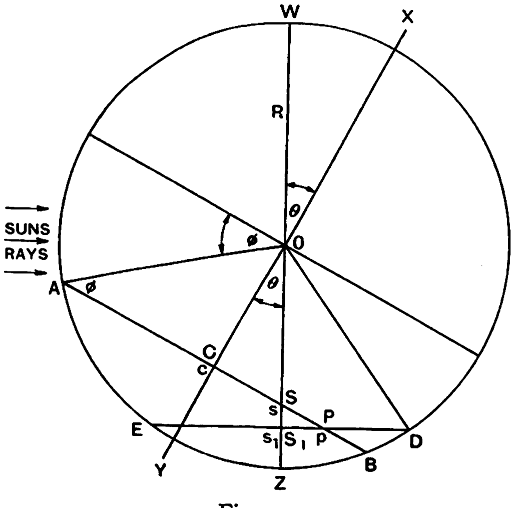


Fig. 1

APPENDIX.

Calculation of the height at which the sun is shining above a point on the earth's surface at a given time before sunrise at that point, the latitude being known.

The calculation in this case is for mid-summer in the southern hemisphere.

Consider the earth as a sphere *WAEZBD* (Fig. 1), with axis of rotation *XY*, and the sun's rays as a parallel beam making an angle $90° - \theta$ with the earth's axis of rotation. Fig. 1 represents this as seen from a direction at right angles to *XY* and to the direction of the sun's rays.

In the figures, capital letters will represent points on the surface of the sphere; small letters, points on the section in the plane of the paper. *O* is the centre of the sphere, *XY* the axis of rotation. *WZ* will be the sunrise belt.

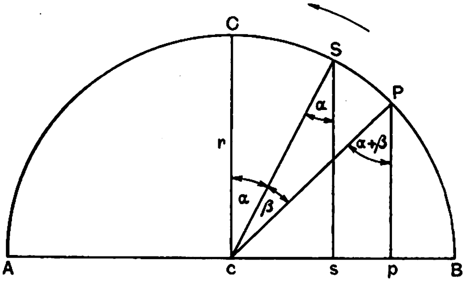


Fig. 2

Let ϕ be the latitude of the point under consideration (*P*), *R* the radius of the sphere, and *ACB* and ES_1D plane sections through *P* perpendicular to *XY* and *WZ* respectively.

Then
$$Ac = R\cos\phi = r.$$
$$Oc = R\sin\phi.$$
$$cs = Oc\tan\theta.$$

Now considering the section *ACB* (Fig. 2):

$$\alpha = \sin^{-1}\frac{cs}{r} \text{ (approx. since } \alpha \text{ is small)}$$

and $\beta = 360 \times \frac{t}{24}$ degrees. [Where t = time to go from *P* to *S*, *i.e.*, time before sunrise (in hours).]

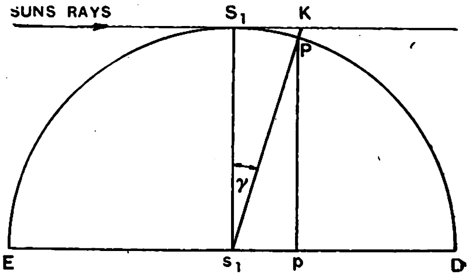


Fig. 3

Also $cp = r\sin(\alpha + \beta)$

and $sp = cp - cs$;

from which we can find the distance sp.

Again, in Fig. 1, $ps_1 = sp\cos\theta$.

Also $Os = Oc/\cos\theta$,

and $ss_1 = sp\sin\theta$,

and $s_1D = \sqrt{R^2 - Os_1^2} = r_1$,

whence we get r_1, the radius of the section ES_1D.

Now consider the section ES_1PD, Fig. 3.

We have found s_1p, and s_1S which $= s_1D = r_1$.

Now $\gamma = \sin^{-1}\frac{s_1p}{r_1}$ (approx.)

and $\frac{r_1}{r_1 + h} = \cos\gamma$

[Where $h = PK$ = height required.]

Therefore $r_1 = \cos\gamma\,(r_1 + h)$

and $h = \frac{r_1(1 - \cos\gamma)}{\cos\gamma}$.

Thus, by substituting the appropriate values for θ, ϕ and R, h can be calculated. By repeating the calculation for several values of t a graph may be drawn showing the relation between t and h.

Retro-action in Amplifiers.

By H. A. Thomas, M.Sc.

Introductory.

THE study of the effects produced by retro-action or, as it is sometimes called, reaction, feed-back, or back-coupling, is one which is made exceedingly difficult by virtue of the complexity of the circuits involved and by the ambiguity which lies beneath the various assumptions usually made in such an analysis.

A true physical conception of all that is taking place in an amplifier is hard to obtain and one is forced to make certain assumptions in order to obtain a satisfactory working basis. These assumptions have not yet been shown to be generally true, and only the simplest cases can as yet be applied. Certain experimental properties are well known and these properties can be partially explained by the use of certain theories.[*]

The object of this paper is to demonstrate some of the general properties of retro-action and to analyse what conditions have to be fulfilled so that retro-action may advantageously be used in an amplifier.

Types of Retro-action.

Retro-action in an amplifier is its property of feeding back energy from the output end to the input end, and thus modifying the normal amplification which it would possess if no such feed-back of energy took place.

Suppose 1/1,000 of a volt is applied to the input of an amplifier, and the amplification is 1,000, then the output will be 1 volt. Now suppose by some means 1/4,000th part of the output voltage leaks back to the input. The input will now have $\left[\frac{1}{1000}+\frac{1}{4000}\right]$ of a volt impressed upon it, and this in turn is amplified 1,000 times, giving $1\frac{1}{4}$ volts output, which again gives $\frac{5}{16000}$th part of a volt to the input, and so on. It is clear that the original 1/1,000th of a volt will give more than 1 volt at the output, and therefore the amplification has been increased above the normal amount.

In this case the effect of retro-action is to increase the overall amplification, and this happens when we deliberately insert special "reaction" coils whose function is to so feed back energy to the input. Due to the inherent capacities of the valves, we sometimes get a feed-back effect which may produce an increase in amplification, or if it is too great may produce instability and self-oscillation. This type of reaction is responsible for thei nstability of multi-stage high frequency amplifiers, and neutrodyne arrangements are intended to insert a negative reaction to counterbalance the inherent positive reaction due to the valves. Again, back reaction can take place from one coupling unit to the previous one, as in the case of open transformers. Screening is now adopted to minimise this type of coupling. In audio-frequency amplifiers, the reaction may be acoustic, in which case the output sound energy mechanically vibrates sympathetically the initial valves of the amplifier, producing a sustained ring or howl in the limiting case when self-oscillation is produced. This is partially overcome by anti-vibration valve holders.

Since this feed-back of energy may in many cases be a great advantage, enormously increasing the sensitivity of an amplifier and yet in other cases may reduce the amplification or produce self-oscillation, we will examine the conditions necessary to produce any one of these three modifications to the normal behaviour of an amplifier.

Examination of the Retro-action Effect.

For the purpose of this discussion, we are going to assume that the amplification is distortionless, and that we are applying sinusoidal waves of potential, *i.e.*, we shall assume we are working on the straight portions of the valve characteristics. We shall also assume that reaction from the output to the input takes place either by means of a special circuit for that purpose, or by means of the amplifier itself, but in the latter case we must assume that the amplifier is a unit. We cannot consider feed-back effects from stage to stage, as this would introduce too great a complexity.

---

[*] C. Gutton, "On the amplification and maintenance of oscillations in an amplifier," *L'Onde Elect.* 1, 261,347, 1922.

V. G. Vallauri, "On the operation of 3-electrode tubes in radio teleg.," *L'Elettrotecnica* 3, 1917.

G. Filippini, "Contribution to the general theory of amplifiers with reaction," *L'Elettrotecnica* 11, 914–922, 1924.

L. Brillouin, "Resistance Amplifiers," *L'Onde Elect.* 1, 7,101, 1922.

Let V_0 be the peak value of the injected sine wave of E.M.F. to the grid of the amplifier, whose instantaneous value is v_0 and let E_0 be the peak value of the sine wave of output E.M.F. produced by the amplifier. Then $\frac{E_0}{V_0}$ is the overall amplification of the system, neglecting any input circuit or reaction effects.

Let us call this *normal amplification coefficient*

$$k = \frac{E_0}{V_0} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Now, if as a result of retro-action, the output is changed from E_0 to E, we shall call $\frac{E}{V_0}$, the total or *final amplification coefficient*, and thus we can call this coefficient

$$K = \frac{E}{V_0} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Now K may be greater or less than k depending on whether the effect of back reaction is to increase or diminish the amplification.

If we put $K = Ck$, C will be a coefficient expressing the final amplification in terms of the normal amplification, and we can call it the *reaction coefficient*.

$$C = \frac{K}{k} \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

If $C > 1$, the effect of the reaction is to increase the amplification, but if $C < 1$ the final amplification is less than the normal.

Now consider the effect of a sinusoidal input applied to the grid of the amplifier of the form

$$v_0 = V_0 \sin(\omega t + \alpha) \quad \ldots \quad (4)$$

This will give rise to an output E.M.F. k times this value, due to the normal amplification coefficient, and therefore represented by

$$e_0 = E_0 \sin(\omega t - \beta) \quad \ldots \quad (5)$$

The angular difference between these two E.M.F. vectors is clearly $(\alpha + \beta)$ and this must therefore represent the phase lag produced by the amplification process. This lag will, of course, depend upon the nature of the circuits and also upon the frequency. We shall assume that this frequency is constant throughout our investigation. We can, therefore, represent the total phase lag due to the amplifier by

$$\gamma = (\alpha + \beta) \quad \ldots \quad \ldots \quad (6)$$

Now, this potential e_0 in the output circuit produces a small E.M.F. in the input due to the retro-action property which we are assuming to be condensed into one unit. We will call this fed-back E.M.F. v_1 and its peak value V_1, and we will denote the phase lag produced between the output and this new E.M.F. by θ_0. Now this E.M.F. will be superimposed on the original v_0, but it must be added vectorially owing to its difference in phase.

$\frac{E_0}{V_1}$ represents the output E.M.F. divided by this new fed-back E.M.F., and will be a large number in most practical cases. Call this ratio 'x.'

Then $$x = \frac{E_0}{V_1} = \frac{kV_0}{V_1} \quad \ldots \quad \ldots \quad (7)$$

If we denote the total phase lag from the first input to the new added fed-back input by θ, we have

$$\theta = \theta_0 + \gamma = \theta_0 + \alpha + \beta \quad \ldots \quad (8)$$

Now the type of coupling will vary this phase lag θ_0 and therefore θ, and the degree of coupling will vary x.

If $\frac{1}{x}$ is large, the coupling is tight, but if $\frac{1}{x}$ is nearly zero, the coupling is loose, and when $\frac{1}{x} = 0$ there is no feed-back. $\frac{1}{x}$ may therefore be considered as the coupling coefficient.

The first fed-back component of E.M.F. can be represented by the equation

$$v_1 = V_1 \sin(\omega t + \alpha - \theta) \text{ from (4)} \quad \ldots \quad (9)$$

since it lags by θ behind the original applied

E.M.F., and since $V_1 = \frac{E_0}{x}$ we have

$$v_1 = \frac{E_0}{x} \sin(\omega t + \alpha - \theta) \quad .. \quad (10)$$

By the normal process of amplification, this E.M.F. v_1 is amplified k times, giving an output

$$e_1 = \frac{k}{x} E_0 \sin(\omega t - \beta - \theta) \text{ from (5)}$$

$$= \frac{k^2}{x} V_0 \sin(\omega t - \beta - \theta) \text{ from (7)} \quad (11)$$

This output component of E.M.F. now establishes a new input component v_2 by virtue of the feed-back.

Therefore, as before, we have

$$v_2 = \frac{e_1}{x} \text{ and lagging } \theta_0 \text{ behind } e_1.$$

So using (11) for e_1, we have

$$v_2 = \frac{k^2}{x^2} V_0 \sin(\omega t - \beta - \theta - \theta_0)$$

$$= \frac{k^2}{x^2} V_0 \sin(\omega t + \alpha - 2\theta) \quad .. \quad (12)$$

since $\theta = \theta_0 + \alpha + \beta$ from (8)

and this gives a second output E.M.F.

$$e_2 = \frac{k^2}{x^2} E_0 \sin(\omega t - \beta - 2\theta) \quad .. \quad (13)$$

We can now write down the successive output components that make up the total output produced. They are

$$\left.\begin{aligned} e_0 &= E_0 \sin(\omega t - \beta) \\ e_1 &= \frac{k}{x} E_0 \sin(\omega t - \beta - \theta) \\ e_2 &= \frac{k^2}{x^2} E_0 \sin(\omega t - \beta - 2\theta) \\ e_3 &= \frac{k^3}{x^3} E_0 \sin(\omega t - \beta - 3\theta) \\ e_4 &= \frac{k^4}{x^4} E_0 \sin(\omega t - \beta - 4\theta) \end{aligned}\right\} \quad .. \quad (14)$$

and so on.

It is clear that the sum of these E.M.F. vectors gives the resultant output and the sum is that of a geometrical progression whose common ratio is $\frac{k}{x}$, whilst the phase angle lag between each term forms an arithmetical progression with a common difference of θ.

We can best examine the nature of this summation by graphical treatment.

In Fig. 1, let OV_0 represent the applied E.M.F. to the amplifier delivered by the tuned circuit system. Then since γ is the total phase lag due to the amplifier alone, we can represent the first output component by $OA = E_0 = kV_0$.

The next output component will be $AB = \frac{k}{x} E_0$ in magnitude and displaced by an angle θ due to the lag caused by the feed-back and amplifier. BC will be the next component and equals $\frac{k}{x} \times AB$ again displaced by θ, and so we shall complete a polygon having an infinite number of sides and arrive at a resultant limiting point R. The vector OR clearly represents the sum of the progression, and in this case is greater than OA.

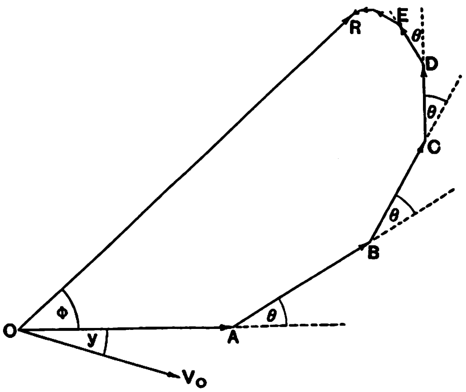


Fig. 1

So in the diagram $\frac{OA}{OV_0} = k$ the normal amplification of the amplifier, $\frac{OR}{OV_0} = K$ the total amplification when feed-back is considered, and since $K = Ck$ by definition (3), the reaction coefficient C is represented by $\frac{OR}{OA}$, which is greater than unity in this case. It is clear that this condition is obtained when $\frac{k}{x}$ is less than unity and when the angle θ is acute.

In Fig. 2, the ratio $\frac{k}{x}$ is again less than unity, but θ is obtuse.

We see here that the resultant OR is less than OA, and therefore K is less than k and the reaction coefficient C is less than unity. The effect of the back coupling is thus to reduce the amplification to a value below the normal value k.

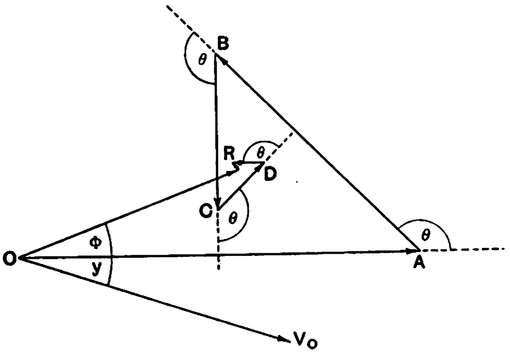


Fig. 2

If the ratio $\frac{k}{x}$ is greater than unity, it is clear that whatever value θ may possess, the polygon increases without limit and the resultant OR becomes infinitely large, however small OA may be. In this case the system is unstable and self-oscillation commences.

We shall therefore only consider the case when $\frac{k}{x}$ is less than unity.

The Maximum Value of Amplification.

We have seen that to obtain the value of E, the resultant output E.M.F. represented by OR and the phase angle Φ, it is necessary to obtain the vectorial sum of the series $\Sigma_{s=0}^{\infty} e_s$. To do this let us represent the vectors E_0, E_1, E_2, etc. by the straight lines OE_0, OE_1, OE_2, etc., respectively in Fig. 3, equal in magnitude to the vectors E_0, E_1, E_2, and such that the angles AOE_1, AOE_2, AOE_3, etc., are θ, 2θ, 3θ, etc., respectively. Then we have to find the sum of these vectors.

Taking the general case of a vector OE, we can express this vector in terms of a real and an imaginary quantity, the real value being the component of the vector along the axis OA and the unreal value, the component perpendicular to OA.

Thus $E_0 p^s (\cos s\theta + i \sin s\theta) = E_0 p^s e^{is\theta}$ (15)

where $p = \frac{k}{x}$

The resultant sum R can thus be expressed in the form

$$R = E_0 \Sigma_{s=0}^{\infty} Z^s \quad .. \quad (16)$$

where $Z = pe^{i\theta}$ .. .. (17)

The series is clearly a geometrical one, and the condition for convergence is as before that $p < 1$. Under these conditions, the sum

$$\Sigma_{s=0}^{\infty} Z^s = \frac{1}{1 - Z} \quad .. \quad (18)$$

and therefore the resultant $R = E_0 \frac{1}{1 - Z}$ (19)

The phase lag between the resultant and the first E.M.F. component is given in terms of the ratio of the real and imaginary components of the complex factor R.

Using the trigonometrical form

$$\frac{1}{1 - p(\cos\theta + i \sin\theta)} = \frac{1}{1 - Z} \quad .. \quad (20)$$

where $p = \frac{k}{x}$, we can represent the complex factor R by the following equation

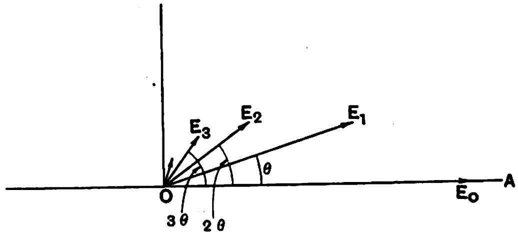


Fig. 3

$$R = a + ib = \frac{1}{(1 - p\cos\theta) - ip\sin\theta} \quad .. \quad (21)$$

This gives the real component

$$a = \frac{1 - p\cos\theta}{p^2 - 2p\cos\theta + 1} \quad .. \quad (22)$$

and the unreal component

$$b = \frac{p\sin\theta}{p^2 - 2p\cos\theta + 1} \quad .. \quad (23)$$

The magnitude of $R = a + ib$ is given by $\sqrt{a^2 + b^2}$ and the angle Φ by $\sin\Phi = \frac{b}{\sqrt{a^2 + b^2}}$

Therefore

$$R = \sqrt{a^2 + b^2}$$

$$= \sqrt{\frac{1 + p^2 \cos^2 \theta - 2p \cos \theta + p^2 \sin^2 \theta}{(p^2 - 2p \cos^2 \theta + 1)^2}}$$

$$= \sqrt{\frac{p^2 - 2p \cos \theta + 1}{(p^2 - 2p \cos \theta + 1)^2}}$$

$$= \frac{1}{\sqrt{(p^2 - 2p \cos \theta + 1)}} \quad \ldots \quad \ldots (24)$$

and

$$\sin \Phi = \frac{p \sin \theta \sqrt{(p^2 - 2p \cos \theta + 1)}}{(p^2 - 2p \cos \theta + 1)}$$

$$= \frac{p \sin \theta}{\sqrt{p^2 - 2p \cos \theta + 1}} = Rp \sin \theta \quad (25)$$

$$\text{So } E = \frac{E_0}{\sqrt{p^2 - 2p \cos \theta + 1}} \quad \ldots \quad \ldots (26)$$

$$\text{and } K = \frac{k}{\sqrt{p^2 - 2p \cos \theta + 1}} \quad \ldots \quad \ldots (27)$$

In the limiting case, on the point of oscillation $p = 1$, and we get

$$E = \frac{E_0}{2 \sin \frac{1}{2}\theta} \text{ and } K = \frac{k}{2 \sin \frac{1}{2}\theta} \quad \ldots (28)$$

As p tends towards unity—*i.e.*, as the feed-back is increased—and as θ tends towards zero, we see that the resultant output E increases towards an infinite value and the amplification has greatly increased. Under these conditions the amplifier is very sensitive but very unstable. The slightest variation in p or θ will produce the oscillatory condition. Now usually the angle θ is defined in terms of the circuit arrangements and an increase of coupling will vary $p = \frac{k}{x}$, since $\frac{1}{x}$ defines the degree of coupling. We will therefore assume θ to be constant and consider for any given value of θ the maximum amplification that is possible by adjusting the feed-back coupling.

To do this we equate $\frac{dE}{dp}$ to zero, and we find that the optimum condition is $p = \cos \theta$ and the maximum value of E is given as

$$E_{\max} = \frac{E_0}{\sin \theta} \quad \ldots \quad \ldots (29)$$

$$\text{and} \qquad K_{\max} = \frac{k}{\sin \theta} \quad \ldots \quad \ldots (30)$$

We see that further increase of coupling beyond this value leads to a reduction in amplification, and thus for a given circuit arrangement we cannot increase the amplification by merely adjusting the magnitude of the feed-back effect by any of the ordinary methods.

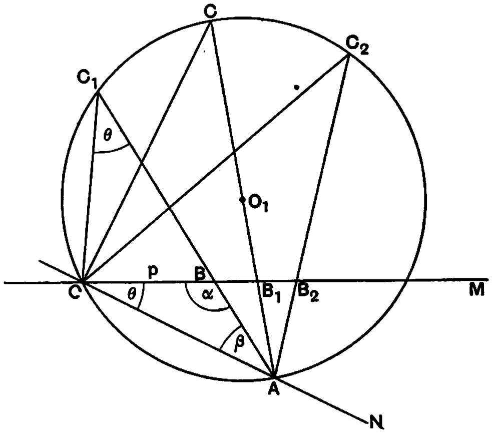


Fig. 4

Summing up the analysis, we see that if we assume the reaction effect to be due to a specific coupling arrangement, the maximum amplification that can possibly be obtained is dependent upon $\frac{k}{x}$ and θ. When $\frac{k}{x}$ is less than 1, the amplifier is stable and the coupling may make C greater or less than unity depending on whether θ is acute or obtuse respectively. When $\frac{k}{x} = 1$, the coupling is such as to compensate exactly for the losses in the circuit, and then the resistance of the input circuit has been reduced to zero, and finally, when $\frac{k}{x}$ is greater than unity, the coupling is such as to more than compensate for all the losses, and therefore oscillations are set up and maintained, and the amplifier becomes unstable. The resistance of the input circuit has been reduced to a negative value.

Graphical Representation of the Retroactive effect.

We can represent the results we have obtained by a simple graphical construction as follows:—

In Fig. 4, consider a line OM representing the vector E_0. Now from O measure a length OB equal in magnitude to the value p. Set out from O the line ON, making an angle equal to θ with OM and to the same scale measure $OA = 1$ along ON.

Thus

$$\overline{OA} > \overline{OB}$$

and in the triangle OAB

$$\overline{AB}^2 = p^2 + 1 - 2p\cos\theta.$$

Now $C = \dfrac{K}{k} = \dfrac{1}{\sqrt{p^2 - 2p\cos\theta + 1}}$ from (27).

Hence $$C = \frac{1}{\overline{AB}}$$

Since $\overline{OA}$ was made equal to unity, we require to know the ratio $\dfrac{\overline{OA}}{\overline{AB}}$ to determine C. Draw OC_1 at an angle AOC_1 equal to ABO and produce AB to C_1. From the similar triangles we see that $\dfrac{AC_1}{OA} = \dfrac{OA}{AB}$, and therefore $\overline{AC_1} = C$. Now since the angle $OCA = \theta$ and is constant when p varies, the locus of point C_1 will be a circle in which OA is a segment. When α becomes a right angle we know that the angle AOC is also a right angle and thus AC is the diameter of the circle. The middle point O_1 of this line gives the centre of the circle.

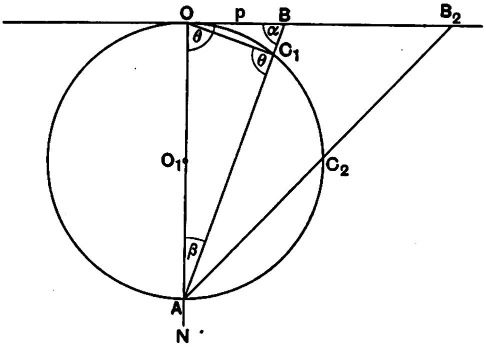


Fig. 5

We see that the maximum value that C may have is when AC becomes the diameter of the circle. Then

$$AC = \frac{OA}{\sin\theta}, \text{ i.e. } C = \frac{1}{\sin\theta}$$

as given in equation (30). The phase angle Φ between the first output vector E_0 and the final resultant vector OR in Fig. 1 is given by the angle β in Fig. 4.

It is important to note that the value of C so obtained is only applicable to the case when $p<1$, *i.e.*, when $OB<OA$. When $p>1$, the stable condition is no longer maintained.

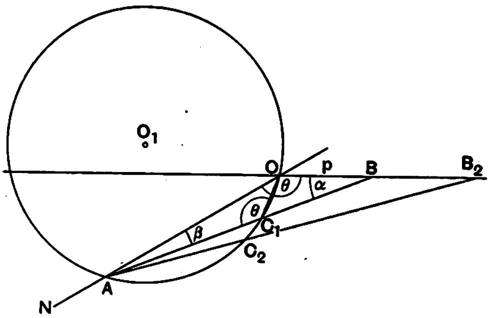


Fig. 6

Now suppose the angle θ is a right angle instead of being acute, as shown in Fig. 5. In this case AO becomes the diameter of the circle and is made equal to unity. As "p" rises from O to unity AC falls from $AO = 1$ to AC. So we see that, whatever coupling we may use, we cannot get a total amplification K greater than the normal value k.

Lastly, when θ is obtuse we obtain the conditions shown in Fig. 6, from which we see that AC is always less than AO, which is made unity as before. This means that, whatever value p may have, the effect of the coupling is to reduce the overall amplification making K less than the normal amplification coefficient k.

Referring to Fig. 4, we see that the maximum amplification is obtained when AC is a maximum, that is when $OB_1 = p$ is some definite optimum value less than $OA = 1$. The amplifier is stable, and we can increase p until its value reaches unity. The maximum value that OB may have is therefore $OB_2 = OA = 1$, and then the value of C is given by the length AC_2, which is less than AC_1, the maximum value. C may thus lie on the arc of the circle OC_1CC_2 but cannot lie to the right of C_2, as this gives p greater than 1 and therefore the oscillatory condition. It is interesting to note that in this case the maximum amplification falls when near to the oscillation point, which means that if a coil or coupling condenser was being used for reaction, increase of this coupling past a certain point would reduce the overall amplification. Similarly in Figs. 5 and 6 for the case of θ equal to a right angle or an obtuse angle respectively, we see that the amplification falls from the value OA to the value AC_2, where $OB_2 = OA = 1$ in both cases. Here the effect of reaction is to reduce the amplification until the fed-back E.M.F. is equal to the component E.M.F. producing it, and when this condition is obtained the amplifier becomes unstable.

It will be noticed from Fig. 4 that if θ is very small, the point of maximum amplification occurs when the reaction is greatest, and this is usually so in most simple practical circuits.

A German H.T. Mains Unit with Glow Discharge Rectifier.

An interesting mains unit made by Dr. Georg Seibt is described in *Elektrotechnische Zeitschrift* of 24th November, 1927. The connections are as shown in Fig. 1, which also gives the value of the components employed. Fig. 2 shows two sectional views of the rectifying valve. It is called an " Anotron " and is a glow discharge valve with a cathode above and two anodes below. The cathode is coated with an alkali nitrogen compound which gives off nitrogen at about 300° C. and frees the alkali; any traces of oxygen are thus absorbed. It is claimed that, unlike other glow discharge valves, the " Anotron " maintains constant characteristics. The absence of any heated filament increases the life of the valve and also does away with the necessity of a special filament-heating secondary winding on the transformer. By means of a 10,000 ohm potentiometer, grid bias voltages from 1 to 15, detector voltages from 30 to 70, low-frequency amplifier voltages from 80 to 130, and a power amplifier voltage of 180 can be tapped off.

G. W. O. H.

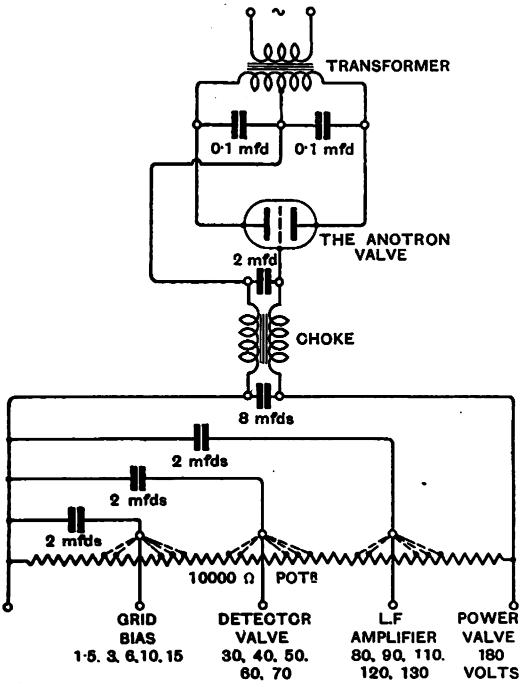


Fig. 1.—*Circuit connections of the mains unit.*

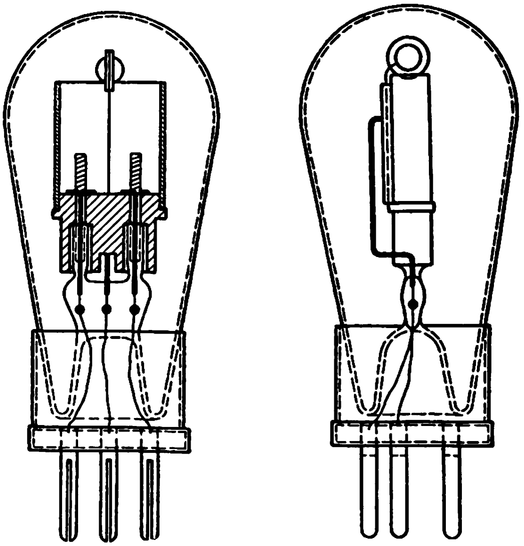


Fig. 2.—*Sectional views of the " Anotron " valve.*

The Power in a Modulated Oscillation.

By *E. Howard Robinson.*

MODULATED oscillations are becoming increasingly important both in radio engineering and line work where modulated carrier currents are employed. So far the present writer has not seen any published information which makes it possible to interpret voltmeter or ammeter readings in terms of power dissipated in the case of circuits carrying modulated high-frequency carrier currents.

In ordinary electrical engineering we deal with A.C. of simple sine-wave form and constant amplitude, the calculations in connection with which are well known. The relation between voltage V and time t is

$$V = V_0 \sin \omega t$$

and we know that if this voltage is applied across a resistance R the power dissipated in the resistance is $\frac{V_0^2}{2R}$, the value $\frac{V_0}{\sqrt{2}}$, termed the R.M.S. voltage, being usually employed in specifying alternating voltages.

If, however, the main frequency voltage is not of constant amplitude but is varied harmonically in accordance with another frequency, our usual A.C. calculation does not hold. It might appear at first sight, since the A.C. peak voltages are varied equal amounts above and below the normal value, that the power would average out to the same value as that obtained in the absence of modulation. The following simple calculations show that this is by no means the case.

Whatever the particular circuit under consideration—it may be simply a condenser or inductance or a more complex system of capacities, inductances and resistances—it may be reduced to one equivalent reactive component in series with an equivalent non-reactive component which we shall designate as a resistance R. It is required to arrive at the watts dissipated in R:

Let V = the voltage across R at any instant.
t = the instantaneous time value.
$\omega_1 = 2\pi$ times the modulation frequency.
$\omega = 2\pi$ times the carrier frequency.
V_0 = the peak voltage.
m = the modulation ratio, *i.e.*, $100\,m$ = percentage modulation.

For simplicity only the case of one modulation frequency at a steady amplitude is considered. We have three important cases to consider, namely: (*a*) ordinary modulation, where the carrier frequency and two side-bands are present; (*b*) two side-bands without carrier, and (*c*) one side-band alone.

(a) Ordinary Modulation.

We have a carrier-frequency oscillation modulated by a simple harmonic variation of its normal amplitude at a frequency of $\frac{\omega_1}{2\pi}$, *i.e.*,

$$\begin{aligned} V &= (V_0 + mV_0 \sin \omega_1 t) \sin \omega t \\ &= V_0 \sin \omega t + \frac{mV_0}{2} \cos (\omega - \omega_1)t \\ &\quad - \frac{mV_0}{2} \cos (\omega + \omega_1)t \quad .. \quad (1) \end{aligned}$$

The first of these terms represents the steady carrier component, while the other two represent the two side-bands.

Now it is well known that if we have a number of simple sine (or cosine) waves of R.M.S. values V_1, V_2, V_3, etc., the resultant R.M.S. value V is given by the square-root of the sum of the squares of the component R.M.S. values, *i.e.*,

$$V = \sqrt{V_1^2 + V_2^2 + V_3^2 + \ldots\ldots}$$

Remembering, therefore, that with a simple sine term the R.M.S. is $\frac{1}{\sqrt{2}}$ of the amplitude, we have for the resultant R.M.S. voltage of the three terms in (1):

$$\begin{aligned} V_{\text{R.M.S.}} &= \sqrt{\frac{V_0^2}{2} + \frac{m^2V_0^2}{8} + \frac{m^2V_0^2}{8}} \\ &= V_0\sqrt{\frac{m^2+2}{4}} \end{aligned}$$

The average power expended in a resistance R is the mean square of the voltage divided by R, *i.e.*:

$$\text{Power} = \frac{V_0^2}{R} \times \frac{m^2 + 2}{4} \quad \ldots \quad \ldots \quad (2)$$

(b) Two Side-bands without Carrier.

An ordinary modulated carrier voltage is, as previously shown, represented by

$$V = V_0 \sin \omega t + \frac{mV_0}{2} \cos (\omega - \omega_1)t - \frac{mV_0}{2} \cos (\omega + \omega_1)t$$

If the steady carrier component $V_0 \sin \omega t$ is suppressed we have for the residual voltages

$$V = \frac{mV_0}{2} \cos (\omega - \omega_1)t - \frac{mV_0}{2} \cos (\omega + \omega_1)t \quad \ldots \quad (3)$$

The two terms in this expression represent the two side-bands without the carrier component, and, using the same theorem as before, the resultant R.M.S. voltage is given by

$$V_{\text{R.M.S.}} = \sqrt{\frac{m^2 V_0^2}{8} \times 2} = \frac{mV_0}{2}$$

and

$$\text{Power} = \frac{V_0^2}{R} \times \frac{m^2}{4} \quad \ldots \quad (4)$$

(c) One Side-band Alone.

The expression for two side-bands is given in (3), *i.e.*:

$$V = \frac{mV_0}{2} \cos (\omega - \omega_1)t - \frac{mV_0}{2} \cos (\omega + \omega_1)t$$

One side-band is therefore given by

$$V = \frac{mV_0}{2} \cos (\omega - \omega_1)t \quad \ldots \quad (5)$$

This represents an ordinary cosine wave and therefore

$$\text{Power} = \tfrac{1}{2}\left(\frac{mV_0}{2}\right)^2 \times \frac{1}{R} = \frac{V_0^2}{R} \times \frac{m_2}{8} \quad \ldots \quad \ldots \quad (6)$$

Conclusions.

The problem is really that of determining root-mean-square voltages in terms of the modulation ratio m and the peak voltage V_0 of the original unmodulated carrier component. We see that the ratio $\frac{\sqrt{2}}{1}$ for $\frac{\text{peak voltage}}{\text{R.M.S. voltage}}$ only holds for an unmodulated sine wave, or single side-band, which amounts to the same thing for a steady value of m. The results may be usefully summarised as in the following table. The same relations, of course, hold for corresponding current values as well as for voltages, *i.e.*, I's may be substituted for V's everywhere.

We see that even with 100 per cent. modulation ($m = 1$) in an ordinary radio telephone transmitter only one-third of the total high-frequency power is transmitted in the form of useful modulation component. The other two-thirds carries no intelligence at all. When the modulation is 50 per cent. ($m = \frac{1}{2}$)—quite a reasonably high value for good telephony—the useful power is only one-ninth of the total power sent out.

The term "useful power" as applied to the side-band components may perhaps need some explanation. The steady carrier component need not, in theory, be radiated or even ever generated at the transmitter as its function can perfectly well be fulfilled by a small local oscillator at the receiver. The intensity of the received telephony in such circumstances depends entirely upon the power radiated from the transmitter in the form of side-band components. The presence of the carrier component in the transmission will not in any way add to the strength of reception where a correctly adjusted local homodyne is used. We have an analogy in the case of ordinary line telephony. The direct current from the microphone battery is not sent right along the line to produce the steady flux in the receiver which is necessary for intelligible reception. The A.C. component is separated from the local D.C. by means of a transformer and is transmitted alone, while the necessary steady flux is supplied at the receiver by a permanent magnet.

It can be shown that with a two-side-band transmission half the transmitting power which would be necessary with a one-side-band transmission is required to produce the same effect at the receiver, provided that the homodyne at the receiver is of adequate strength. It is for this reason that a two-side-band system is taken as the basis of usefulness for the present discussion. Of course the practical difficulties in working without the carrier component in the transmission medium in the case of radio telephony constitute an important secondary consideration which, however, does not enter the present discussion.

Type of Waveform.	R.M.S. Voltage (Peak Value of Carrier = V_0).	Power in a Load R.	$\dfrac{\text{Maximum Peak Volts}}{\text{R.M.S. Volts.}}$
Carrier and both side-bands.	$V_0 \times \sqrt{\dfrac{m^2+2}{4}}$	$\dfrac{V_0^2}{R} \times \dfrac{m^2+2}{4}$	$\dfrac{2(m+1)}{\sqrt{m^2+2}}$
Both side-bands without carrier.	$V_0 \times \dfrac{m}{2}$	$\dfrac{V_0^2}{R} \times \dfrac{m^2}{4}$	2
One side-band alone.	$V_0 \times \dfrac{m}{\sqrt{8}}$	$\dfrac{V_0^2}{R} \times \dfrac{m^2}{8}$	$\sqrt{2}$
Carrier alone (no modulation).	$V_0 \times \dfrac{1}{\sqrt{2}}$	$\dfrac{V_0^2}{R} \times \dfrac{1}{2}$	$\sqrt{2}$

An interesting point arises in connection with the interpretation of meter readings in circuits carrying modulated currents. A thermal instrument, such as the usual hot-wire or thermo-junction aerial ammeter, depends upon the rate at which heat is produced in a resistance and it gives therefore an accurate measure of the mean square of the current whatever the waveform. The dial is generally calibrated in amperes, the actual reading being the R.M.S. current, and this is correct both for modulated and unmodulated currents.

When the microphone of an ordinary radio-telephone transmitter is spoken into the reading of a thermal ammeter in the aerial circuit should increase slightly. Systems of modulation where the reading either stays dead constant or decreases when the microphone is spoken into must operate in some freak manner and give rise to distortion.

An approximate method of measuring the modulation ratio m suggests itself in the case of an ordinary telephony transmitter where a rapidly-responding thermo-ammeter is available. Let I_1 be the thermo-ammeter reading in the absence of modulation and I_2 the reading when some fairly steady modulation is applied. If I_0 is the peak value of the unmodulated carrier current ($I_0 \sin \omega t$) we have

$$I_1 = I_0 \times \frac{1}{\sqrt{2}}$$

$$I_2 = I_0 \times \sqrt{\frac{m^2+2}{4}} \quad \text{(see table).}$$

Eliminating I_0 between these two equations,

$$m = \sqrt{\frac{2\,(I_2^2 - I_1^2)}{I_1^2}}.$$

In the particular case of 100 per cent. modulation ($m = 1$)

$$\frac{I_2}{I_1} = \sqrt{\frac{3}{2}} = 1.22.$$

The simple relations given in this article do not, of course, hold for completely interrupted carrier waves of the "I.C.W." type.

Dielectric Losses in Single Layer Coils at Radio Frequencies.

By W. Jackson, M.Sc.

THE results of resistance measurements on single layer coils at radio frequencies have always shown a serious discrepancy between the measured values of resistance and the values computed from the high-frequency resistance formulæ which S. Butterworth† has derived from purely theoretical considerations.

The importance of the dielectric necessarily associated with inductance coils in introducing a source of loss into the coil circuit and therefore in increasing the effective resistance of the coil at radio frequencies has been fully realised. The experiments to be described have been an attempt to measure the magnitude of this added resistance and to enquire whether it was of sufficient magnitude to account for part of this discrepancy.

The dielectric loss may be associated with either the insulated covering on the wire or the mechanical support or former on which the coil is wound. The wire covering may be of silk, cotton or enamel, while the materials used frequently as formers are tubes of ebonite, micarta, paxolin, wood, glass and cardboard.

Any dielectric loss associated with the coil is exhibited as an increase in the effective resistance of the coil, and the magnitude of this increase has been measured at radio frequencies for coils, of exactly similar spacing, inductance and direct current resistance, wound on formers of the above-mentioned materials, using both bare and covered wire.

For this purpose it was necessary to construct a coil having a minimum of solid dielectric, which could be regarded as sensibly devoid of dielectric loss and with which the exactly similar former wound coils could be compared. The photograph of Fig. 1 shows the former constructed for the purpose of winding this standard coil. A brass tube of four inches external diameter and four inches in length was provided at one end with a brass flange and was then grooved approximately 14 turns to the inch. After grooving, the tube and its associated flange was cut axially into 6 sectors, a circumferential space of one-quarter inch being cut between sectors. The sectors were mounted on a brass base plate and the true position of each sector located by two fastening screws passing through radial slots in the flanges. By loosening the screws each sector could be slid radially inwards along the face of the base plate. The sectors were supported at their extreme ends by a removable brass ring placed inside the end of the tube and to which each sector was fastened by screw. A spindle passing through the base plate enabled the former to be supported and at the same time rotated, thus rendering the coil winding a simple process.

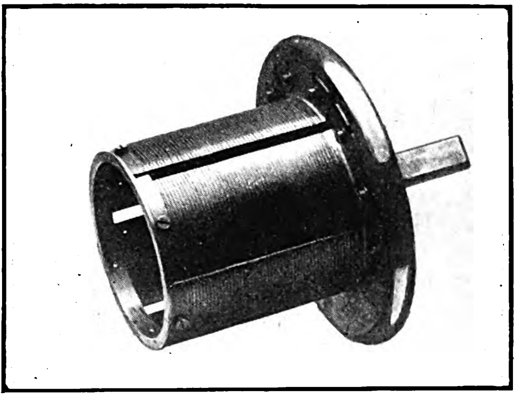


Fig. 1.—*Former for coil winding.*

The coil used throughout as the standard of comparison consisted of 46 turns of No. 20 S.W.G. bare copper wire, the diameter of which was .0357 inch. The pitch of the turns being .0684 inch, provided sufficient spacing between wires to allow the construction of a similar coil of double cotton and enamel-covered wire.

In order to retain the spacing of the wires when the coil was removed from the former a thin stream of molten paraffin wax was poured axially along the coil at each circumferential space between sectors. This was found to give sufficient rigidity to enable measurements to be made on the coil. The coil could be taken from the former by removing the end supporting ring and collapsing the sectors of the former a small distance along the base plate.

---

† *E.W & W.E.* Vol. 3, April, May and July, 1926.

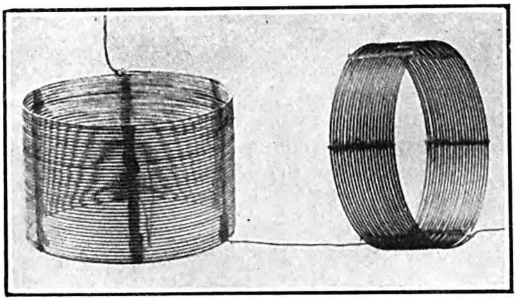


Fig. 2.—*Coils used in tests.*

Two coils wound on the former and used in the tests for comparison with Butterworth's theoretical formulæ are shown in Fig. 2; the smaller was wound with bare No. 20 S.W.G. wire, and the larger with silk covered No. 20 wire.

Coils of the same number of turns as the standard were wound on the various formers given below. Each former had an external diameter of 4 inches, and was grooved in the same manner as the brass former previously described, ensuring exact similarity in overall diameter and in spacing between turns for all the coils tested. The brass former was also used in winding similar coils using silk, cotton, and enamel-covered wire.

(*a*) Ebonite former. Tube, $\frac{1}{4}$ in. thick.
(*b*) Micarta former. Tube, $\frac{1}{4}$ in. thick.
(*c*) Teak wood former. Tube, $\frac{1}{4}$ in. thick.
(*d*) Leatheroid former (consisting of layers of leatheroid sheet held together by shellac varnish and baked). Tube, $\frac{1}{4}$ in. thick.
(*e*) Paxolin former. Tube, $\frac{1}{16}$ in. thick.
(*f*) Cardboard former. Tube, $\frac{1}{8}$ in. thick.

The common direct-current resistance was .380 ohm and the true inductance 173·5 microhenries.

High-frequency Resistance Measurement.

The method of measurement adopted was the "Resistance Variation Method," as this method had been found reliable and accurate. Measurements covered a wavelength range of 300 to 900 metres. The standard resistances used consisted of short lengths of Eureka wire, which could be inserted between two mercury cups connected in the measuring circuit. Normally, the cups were short circuited by a piece of thick copper wire of the same shape as the standard resistances. The latter had values of .888; 1.785; 2.329 ohms, and results using the three resistances in turn were found to agree within 1 per cent.

Measurements on air coils wound with No. 20 S.W.G. single silk-covered, double silk-covered, double cotton-covered, and double cotton- and enamel-covered wire when compared with those on the bare wire standard coil indicated an inappreciable loss due to the wire covering over the entire wavelength range, 300 to 900 metres. This is substantially in agreement with Wilmotte's results on a square single layer coil.*

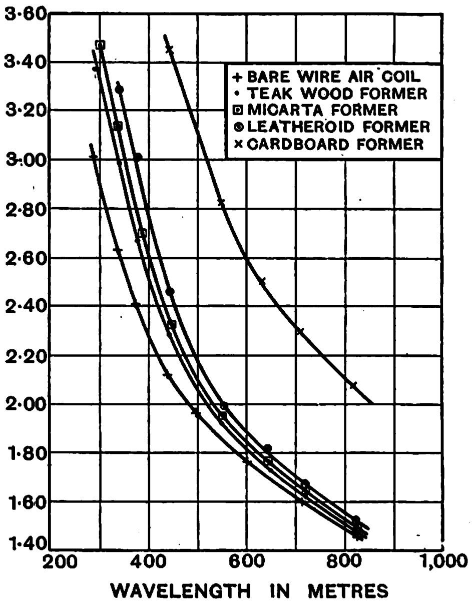


Fig. 3.

A coating of wet shellac to the double cotton-covered wire coil was found to increase the effective resistance by .18 ohm at 300 metres, a percentage increase of 6.0 per cent.

---

* *E.W. & W.E.*, Vol. 2, 1925, p. 481.

The effect of the different formers was, however, very pronounced, as will be seen from the curves of Fig. 3. These show the variation of effective resistance of the coils (*b*), (*c*), (*d*), and (*f*), and of the standard air coil with wavelength.

It is seen that the cardboard former is capable of introducing a resistance of 2.30 ohms into the circuit at 300 metres, which represents a 76 per cent. increase in effective resistance. The extent to which moisture may affect the dielectric loss in such a former will be seen from the following results at a wavelength of 500 metres.

	Effective Resistance (ohms).
Standard bare wire, air coil	1.96
D.C.C. wire. Cardboard former (dry)	3.35
D.C.C. wire. Cardboard former (damp)	7.03

The ebonite and paxolin formers were found to increase the effective resistance of the coil only slightly, the increase at 300 metres in each case being of the order of 3.0 per cent.

Variation of Added Resistance Due to Dielectric Loss with Frequency.

For purposes of theoretical analysis, a coil can be represented by the equivalent circuit of Fig. 4, where L represents the pure inductance, and R the true resistance of the coil; C is a small condenser representing the self-capacity and r a resistance accounting for the dielectric loss.

If this is replaced by an equivalent series circuit consisting of an effective resistance R^1 and an effective inductance L^1, it can readily be shown that ‖

$$R^1 = \frac{R + rC^2\omega^2(L^2\omega^2 + R^2 + rR)}{(1 - LC\omega^2)^2 + (R + r)^2C^2\omega^2}$$

where ω is 2π times the frequency.

Provided that the natural frequency of the coil is not approached; that is, provided $LC\omega^2$ is small compared with unity, and since C is only of the order of a few micro-farads, the above expression may be simplified to

$$R^1(1 - 2LC\omega^2) = R + rL^2C^2\omega^4 \quad .. \quad (1)$$

The dielectric circuit consisting of C and r

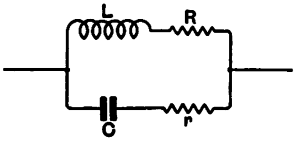


Fig. 4.

has a power factor $P = rC\omega$, which allows equation (1) to be written

$$R^1(1 - 2LC\omega^2) = R + PL^2C\omega^3 \quad .. \quad (2)$$

The term $PL^2C\omega^3$ represents the added series resistance due to dielectric loss, and, since P is fairly constant with change in frequency, is seen, theoretically, to vary as the cube of the frequency.

The results given in Fig. 3 on the various coils enable the variation of added resistance due to dielectric loss with frequency to be checked. Since all the coils are similar, the true high-frequency resistance R, at a given frequency, will be the same in all cases. Measurements of self-capacity indicated that the type of former had no effect on the value of C, the latter being 4.5 $\mu\mu f$ for all the coils.

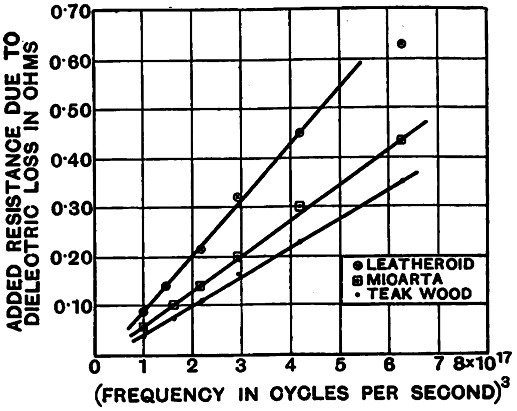


Fig. 5.

It follows then that if the effective resistances of the standard air coil and of a former wound coil at a frequency $\omega/2\pi$ are respectively R_1^1 and R_2^1, the added series resistance due to dielectric loss in the former wound coil is given by

---

‖ *E.W. & W.E.*, Vol. 2, 1925, p. 483.

$$(R_2^1 - R_1^1)\,(1 - 2LC\omega^2)$$

provided that the dielectric loss in the standard coil is negligibly small in comparison, which is the case.

This added resistance has been derived from the results of Fig. 3 for the coils (*b*), (*c*) and (*d*). It is seen from Fig. 5, where the added series resistance is plotted against the cube of the frequency, that this resistance sensibly follows the cube law previously derived theoretically.

This conclusion does not hold in the case of the cardboard former. As the former was not baked before the test, this is probably accounted for by the presence of moisture in the cardboard.

The results serve to show that dielectric loss may be an important factor in determining the effective resistance of a coil at radio frequencies, and to emphasise the deleterious effect of moisture on dielectric loss.

Since the added series resistance due to dielectric loss is given by the expression $PL^2C\omega^3$, the average power factor P of the dielectric circuit of the various coil formers can be calculated from the curves of Fig. 5. These give values for P of .032 for the leatheroid former, .021 for the micarta former and .016 for the teak wood former.

Comparison of Results on Bare Wire Coil with Theoretical Values.

Since the standard bare wire coil can be regarded as devoid of dielectric loss, the measured values of effective resistance, when corrected for self-capacity, can be compared with the calculated values of high-frequency resistance given by Butterworth's equation for short single layer coils.

$$R_n = R_0\left\{1 + F + uG\frac{d^2}{D^2}\right\}$$

where R_n is the resistance at frequency n and R_0 is the direct current resistance. In this formula $1+F = \frac{\sqrt{2z}+1}{4}$; $G = \frac{\sqrt{2z}-1}{8}$ and $z = \pi d\sqrt{\frac{2n}{\rho}}$, d being the wire diameter in cms., and D the pitch of the turns. The factor $u = 3.29 + b/a$, where b is the length of the coil and a its radius.

The measured values of high-frequency resistance can be corrected for self capacity by the formula

$$R = R^1(1 - 2LC\omega^2).$$

The curves of Fig. 6 show the experimental results along with the calculated values. It may be seen that the experimental values are everywhere too high. This may be accounted for by the unknown resistance of the condenser included in the measuring circuit. At a wavelength of 600 metres a condenser power factor of 20.5×10^{-5} is sufficient to account for the discrepancy, although at 300 metres the condenser power factor would require to be 38.2×10^{-5}.

Measurements on other air coils of different turns to the above indicated that power factors of this order would account in all cases for the difference between measured and calculated results.

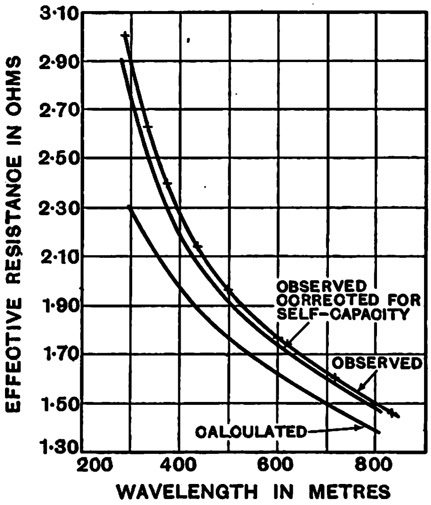


Fig. 6.

It has been stated[§] that the power factor of a good air condenser is of the order of 30×10^{-5}, which justifies the conclusion that if the condenser loss be allowed for Butterworth's formula gives close agreement with experimental values.

The author wishes to express his thanks to the Principal of the Technical College, Bradford, for facilities to carry out the experimental work recorded in the paper.

[§] "Radio Frequency Measurements," Moullin, p. 175.

The Establishment of Formulæ for the Self-inductance of Single-turn Circuits of Various Shapes.

By R. G. Allen, B.Sc., A.R.C.Sc.I., M.I.E.E.

THE more elementary fundamental principles required in this treatment are given in text-books on electrical principles and will be assumed as known. They include :—

(*a*) Laplace's formula which gives the strength of the magnetic field at a point outside a conductor carrying a current of electricity due to a small element of the circuit.

(*b*) That the equivalent number of magnetic lines due to the internal system of lines of magnetic force, or induction, in the material of a conductor carrying current is $\frac{\mu}{2}$ per 10 amperes per linear centimetre of the conductor, μ being the magnetic permeability of the material of the conductor.

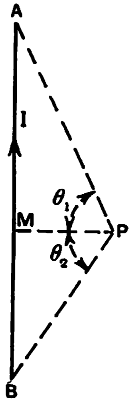


Fig. 1.

(*c*) The strength of the magnetic field at a point *P*, Fig. 1, outside a limited length *AB* of a straight conductor carrying current is

$$\frac{I}{PM}(\sin\theta_1 + \sin\theta_2) \qquad .. \quad (1)$$

I being the current in c.g.s. units and *PM* the distance in cms. of *P* from the axis of the conductor. The latter formula may be readily proved by using Laplace's formula.

The Self-inductance of a Circular Coil having One Turn.

The radius of the circle is *a* cms. and the radius of the wire *r* cms. In Fig. 2, *AB* is a part of the turn of wire and is taken so small that it may be regarded as straight. Its length is taken as *s*.

The first step is to find the number of lines due to *AB*, which threads the element of area between the lines *OM* and *ON*.

By Laplace's formula the strength of the magnetic field due to *AB* at *P* is

$$\frac{AB\cos\theta}{OP^2} = \frac{s\cos\theta}{x^2},$$

the current being 10 amperes.

It follows then that the number of lines of magnetic force threading the shaded element at *P* will be

$$\frac{s\cos\theta}{x^2} \times x\,d\theta\,dx = s\cos\theta\,d\theta\frac{dx}{x}.$$

Therefore the number of external lines due to *AB* threading the area *OMN* will be,

$$s\cos\theta\,d\theta\int_{OH}^{OM}\frac{dx}{x} = s\,d\theta\cos\theta\log\frac{OM}{OH}.$$

Now $OM = 2a\cos\theta$ and $OH = \frac{r}{\cos\theta}$.

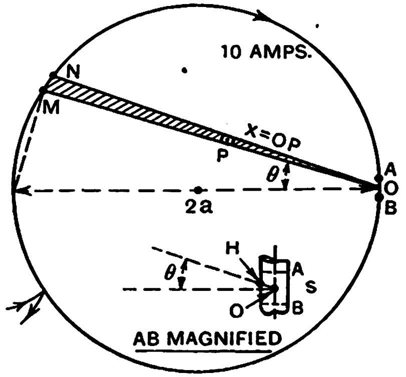


Fig. 2.

The number of lines for *OMN* will be then equal to

$$s\,d\theta\cos\theta\log\frac{2a\cos^2\theta}{r},$$

that is, to

$$s\,d\theta\cos\theta\left(\log\frac{2a}{r} + 2\log\cos\theta\right).$$

The total number of lines threading the whole circular enclosed area due to *AB* will be the integration of the number of lines due to *AB* threading all the elemental areas such as *OMN*. The number of external lines due to *AB* threading the circle will therefore be

$$2s \log \frac{2a}{r} \int_0^{\frac{\pi}{2}} \cos\theta \, d\theta + 4s \int_0^{\frac{\pi}{2}} \cos\theta \log\cos\theta \, d\theta$$

which equals

$$2s \log \frac{2a}{r} \Big[\sin\theta \Big]_0^{\frac{\pi}{2}} + 4s \int_0^{\frac{\pi}{2}} \cos\theta \log\cos\theta \, d\theta,$$

that is:

$$2s \log \frac{2a}{r} + 4s \int_0^{\frac{\pi}{2}} \cos\theta \log\cos\theta \, d\theta.$$

The integration of the second term may be found by integrating by parts, and using

$$\sin^2\theta = 1 - \cos^2\theta,$$

and

$$\int \frac{d\theta}{\cos\theta} = \log \frac{1 + \sin\theta}{\cos\theta}.$$

Its value is

$$\sin\theta \log\cos\theta + \int \frac{d\theta}{\cos\theta} - \int \cos\theta \, d\theta$$

Therefore this integration is

$$\Big[\sin\theta \log\cos\theta - \sin\theta + \log(1 + \sin\theta) - \log\cos\theta \Big]_0^{\frac{\pi}{2}}$$

$$= -1 + \log 2 = -1 + 2.3 \times 0.3 = -0.31.$$

Thus the number of external lines threading the circle due to *AB* is

$$2s \log \frac{2a}{r} - 4s \times 0.31.$$

Now as each part of the circuit equal to *AB* produces the same number of lines of magnetic force in the coil, *s* will be replaced by $2\pi a$ in the value for *L*, the self-inductance of the circuit. Thus

$$L = 4\pi a \left(\log \frac{2a}{r} - 0.62 \right) + \pi a \mu$$

$$= 4\pi a \left(\log \frac{8a}{r} - 2.0 \right) + \pi a \mu.$$

The second term is the internal magnetic linkages for the circuit. This result multiplied by 10^{-9} will give the self-inductance of the coil in henries, or by 10^{-3} in microhenries. The logarithm is to the base *e*.

The Self-inductance of a Square Coil having One Turn.

The mean length of a side is *a* cms. and *r* is the radius of the wire. The strength of the magnetic field at *B* due to *AC* (Fig. 3), is by formula (1):

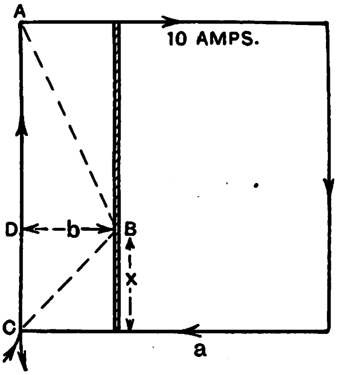


Fig. 3.

$$\frac{1}{b} (\sin CBD + \sin DBA) \, dx \, db,$$

that is

$$\left(\frac{a - x}{\sqrt{b^2 + (a - x)^2}} dx + \frac{x}{\sqrt{b^2 + x^2}} dx \right) \frac{db}{b}.$$

Therefore the number of lines of magnetic force threading the shaded area due to *AC* is

$$\frac{db}{b} \int_0^a \left(\frac{a - x}{\sqrt{b^2 + (a - x)^2}} dx + \frac{x}{\sqrt{b^2 + x^2}} dx \right)$$

which equals

$$\frac{db}{b} \Big[-\sqrt{b^2 + (a - x)^2} + \sqrt{b^2 + x^2} \Big]_0^a$$

that is

$$\frac{2db}{b} \left(\sqrt{b^2 + a^2} - b \right)$$

The total external lines threading the square due to *AC* will then be

$$2 \int_r^a \left(\frac{\sqrt{a^2 + b^2}}{b} - 1 \right) db \quad .. \quad (2)$$

Now the integration of $\dfrac{\sqrt{a^2 + b^2}}{b} db$ is

$$a \left\{ \frac{\sqrt{a^2 + b^2}}{a} + \log \frac{b}{\sqrt{a^2 + b^2} + a} \right\},$$

so that (2) becomes

$$2\left[\sqrt{a^2+b^2}+a\log\frac{b}{\sqrt{a^2+b^2}+a}-b\right]_r^a \cdot\cdot\ (3)$$

which equals

$$2a\left(\sqrt{2}-2+\log\frac{2a}{r(\sqrt{2}+1)}\right)$$

$$=2a\left\{\log\frac{2a}{r}-\left[2-\sqrt{2}+\log(\sqrt{2}+1)\right]\right\}$$

$$=2a\left(\log\frac{2a}{r}-1.47\right)=2a\left(\log\frac{4a}{r}-2.16\right).$$

As each side produces the same number of lines of magnetic force in the coil,

$$L=8a\left(\log\frac{4a}{r}-2.16\right)+2a\mu.$$

This multiplied by 10^{-3} will give the self-inductance of the square coil in microhenries.

The Self-inductance of a Rectangular Coil having One Turn.

The mean lengths of the adjacent sides are taken as A and B cms., and the radius of the wire r cms. This value of L is readily found from the expression (3), using limits B and r and multiplying by 2 for the two like sides.

Thus

$$4\left[\sqrt{A^2+B^2}+A\log\frac{B}{\sqrt{A^2+B^2}+A}-B-A-A\log\frac{r}{2A}\right],$$

and for the other two sides

$$4\left[\sqrt{A^2+B^2}+B\log\frac{A}{\sqrt{A^2+B^2}+B}-A-B-B\log\frac{r}{2B}\right].$$

This gives for L the value

$$8\sqrt{A^2+B^2}-8(A+B)-4A\log(\sqrt{A^2+B^2}+A)-4B\log(\sqrt{A^2+B^2}+B)+4(A+B)\log\frac{2AB}{r}+(A+B)\mu.$$

Multiply by 10^{-3} to get L in microhenries.

The Self-inductance of a Coil having the Form of an Equilateral Triangle with One Turn of Wire.

The mean length of a side is a cms. and the radius of the wire is r cms. The strength of the magnetic field at P due to side AB (Fig. 4) is $\frac{1}{b}(\sin\theta_1+\sin\theta_2)$ for a current of 10 amperes.

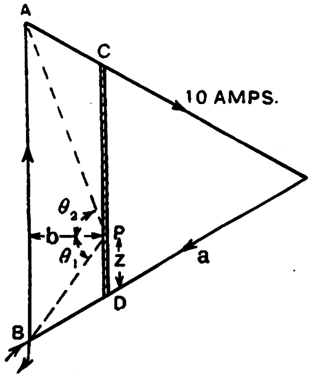


Fig. 4

The number of lines of magnetic force threading the shaded element due to AB will be therefore

$$\frac{db}{b}\int_0^{CD}\left(\frac{z+\frac{b}{\sqrt{3}}}{\sqrt{b^2+\left(z+\frac{b}{\sqrt{3}}\right)^2}}+\frac{a-\left(z+\frac{b}{\sqrt{3}}\right)}{\sqrt{b^2+\left\{a-\left(z+\frac{b}{\sqrt{3}}\right)\right\}^2}}\right)dz,$$

CD being equal to $\left(a-\frac{2b}{\sqrt{3}}\right)$.

This equals

$$\frac{db}{b}\left[\sqrt{b^2+\left(z+\frac{b}{\sqrt{3}}\right)^2}-\sqrt{b^2+\left\{a-\left(z+\frac{b}{\sqrt{3}}\right)\right\}^2}\right]_0^{CD}$$

that is

$$\frac{2db}{b}\left(\sqrt{b^2+\left(a-\frac{b}{\sqrt{3}}\right)^2}-\frac{2}{\sqrt{3}}b\right)$$

or,

$$\frac{4}{\sqrt{3}}\frac{db}{b}\left(\sqrt{\left(b-\frac{\sqrt{3}}{4}a\right)^2+\left(\frac{3}{4}a\right)^2}-b\right)\ \cdot\cdot\ (4)$$

The integration of

$$\sqrt{\left(b-\frac{\sqrt{3}}{4}a\right)^2+\left(\frac{3}{4}a\right)^2}\,\frac{db}{b}$$

may be found as follows :

Let $y=b-\frac{\sqrt{3}}{4}a$, $A=\frac{3}{4}a$, and $k=\frac{\sqrt{3}}{4}a$.

This gives the form

$$\int\frac{\sqrt{y^2+A^2}}{y+k}\,dy \quad \ldots \quad \ldots \quad (5)$$

Assuming that $\sqrt{y^2+A^2}=x-y$,

$$y^2+A^2=x^2-2xy+y^2,$$

so that

$$x^2-2xy=A^2 \quad \ldots \quad \ldots \quad (6)$$

By differentiation,

$$2xdx-2ydx-2xdy=0.$$

Thus, $$dy=\frac{(x-y)}{x}\,dx$$

Also from (6) $$y=\frac{x^2-A^2}{2x}$$

Therefore (5) becomes

$$\frac{1}{2}\int\frac{x^4+2A^2x^2+A^4}{x^4-x^2A^2+2kx^3}\,dx$$

which equals, by division,

$$\frac{1}{2}\int\left(1+\frac{3x^2A^2+A^4-2kx^3}{x^2(x^2+2kx-A^2)}\right)dx.$$

Resolving the second term by the method of partial fractions gives the result as

$$\frac{1}{2}\int\left\{1-\left(\frac{2kx+A^2}{x^2}\right)+\frac{4(A^2+k^2)}{x^2+2kx-A^2}\right\}dx.$$

That is,

$$\frac{1}{2}\int\left[1-\frac{2k}{x}-\frac{A^2}{x^2}+2\sqrt{A^2+k^2}\times\left\{\frac{1}{(x+k)-\sqrt{A^2+k^2}}-\frac{1}{(x+k)+\sqrt{A^2+k^2}}\right\}\right]dx,$$

which equals

$$\frac{1}{2}\int\left(1-\frac{\sqrt{3}\,a}{2x}-\frac{9}{16}\frac{a^2}{x^2}+\frac{\sqrt{3}\,a}{x-\frac{\sqrt{3}}{4}a}-\frac{\sqrt{3}\,a}{x+\frac{3\sqrt{3}}{4}a}\right)dx.$$

Solving equation (6) gives

$$x=y\pm\sqrt{A^2+y^2}$$

$$=\left(b-\frac{\sqrt{3}}{4}a\right)\pm\sqrt{\frac{9}{16}a^2+\left(b-\frac{\sqrt{3}}{4}a\right)^2}$$

Now the limits of b are $\frac{a\sqrt{3}}{2}$ and r, so that the corresponding limits of x taking the root with the positive sign are $\frac{3\sqrt{3}}{4}a$ and

$$r-\frac{\sqrt{3}}{4}a+\sqrt{\frac{9}{16}a^2+\left(r-\frac{\sqrt{3}}{4}a\right)^2}$$

or $$r-\frac{\sqrt{3}}{4}a+\frac{\sqrt{3}a}{2}\left\{1+\frac{4}{3}\frac{r^2}{a^2}-\frac{2}{\sqrt{3}}\frac{r}{a}\right\}^{\frac{1}{2}}$$

As r is taken very small compared with a, this second limit becomes $r+\frac{\sqrt{3}a}{4}-\frac{r}{2}$ very nearly.

For more accurate results, the whole value of the lower limit may be used.

It will be noted that the root with the positive sign has been taken for x. Either root will give the same result, but the former is the more convenient.

Thus the upper limit of x is $\frac{3\sqrt{3}}{4}a$ and the lower limit is $\frac{r}{2}+\frac{\sqrt{3}}{4}a$. Integrating the former result gives

$$\frac{1}{2}\left[x-\frac{\sqrt{3}}{2}a\log x+\frac{9}{16}\frac{a^2}{x}+\sqrt{3}\,a\log\frac{x-\frac{\sqrt{3}}{4}a}{x+\frac{3\sqrt{3}}{4}a}\right]_{\frac{r}{2}+\frac{\sqrt{3}}{4}a}^{\frac{3\sqrt{3}}{4}a}$$

which is equal to

$$\frac{\sqrt{3}}{2}a\log\frac{2a}{3r}.$$

Finally, the number of lines of magnetic force threading the triangle due to AB will be from (4) equal to

$$\frac{4}{\sqrt{3}}\left(\frac{\sqrt{3}}{2}a\log\frac{2a}{3r}-\frac{\sqrt{3}}{2}a\right)$$

and the total number of external lines threading the triangle will be three times this, namely:

$$6a\log\frac{2a}{3r}-6a$$

or

$$6a\left(\log\frac{3a}{r}-2.5\right)$$

Therefore

$$L=6a\left(\log\frac{3a}{r}-2.5\right)+1.5a\mu$$

This will be multiplied by 10^{-3} to give microhenries.

The Self-inductance of a Plane Coil having One Turn and the Form of a Hexagon.

The mean side length of the hexagon is taken as a cms. and the radius of the wire r cms. On account of the limitations of space and the length of the solution, the steps of the latter are merely outlined.

The number of lines of magnetic force in the elemental area PQ (Fig. 5) due to the current in AB was first obtained, and then integrated between the limits $\frac{a\sqrt{3}}{2}$ and r. Those in the elemental area RS due to AB were then obtained and integrated between the limits $a\sqrt{3}$ and $\frac{a\sqrt{3}}{2}$.

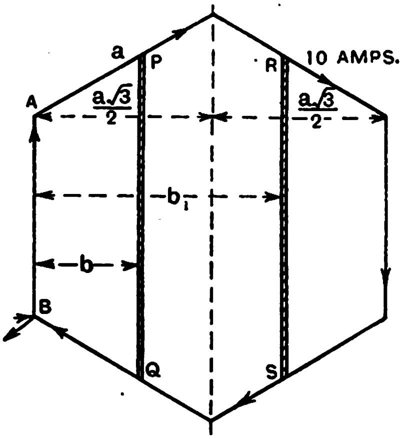


Fig. 5

The result was obtained finally by adding these two integrations, multiplied by 6 for the six sides of the hexagon, and the equivalent internal system of lines of magnetic force, namely, $3a\mu$.

That is, the solution was of the form

$$\frac{24}{\sqrt{3}}\left[\int_{r}^{a\sqrt{3}/2} A\,db+\int_{a\sqrt{3}/2}^{a\sqrt{3}}(B-C)\,db_1\right]+3a\mu,$$

in which the integrations involving A, B, and C are of the same form as expression (5) and solved in the same way. By this method the following formula was obtained.

$$L=12a\left(\log\frac{6a}{r}-1.95\right)+3a\mu.$$

This result, divided by 10^{-3} gives L in microhenries.

A summary of the preceding results is as follows:

Circle mean radius a cms.

$$L=4\pi a\left(\log\frac{8a}{r}-2.0\right)+\pi a\mu.$$

Square mean side length a cms.

$$L=8a\left(\log\frac{4a}{r}-2.16\right)+2a\mu.$$

Rectangle mean side lengths a and b cms.

$$L=8(P-Q)-4\{a\log(P+a)+b\log(P+b)\}+4Q\left(\log\frac{2ab}{r}+\frac{\mu}{4}\right),$$

in which $P=\sqrt{a^2+b^2}$ and $Q=a+b$.

Equilateral triangle mean side length a cms.

$$L=6a\left(\log\frac{3a}{r}-2.5\right)+1.5a\mu.$$

Hexagon mean side length a cms.

$$L=12a\left(\log\frac{6a}{r}-1.95\right)+3a\mu.$$

In these formulæ r, the radius (cms.) of the wire, is regarded as very small compared with the perimeter of the circuit; μ is the magnetic permeability of the material of the wire and is assumed constant; the logarithms are to base e; and the value of L given has to be multiplied by 10^{-3} to give the result in microhenries.

The Harmonic Comparison of Radio-Frequencies by the Cathode-Ray Oscillograph.

By T. S. Rangachari, M.A. (Indian Institute of Science, Bangalore, India).

ONE of the many uses of the Cathode-Ray Oscillograph in a high-frequency laboratory is the harmonic comparison of radio-frequencies. For this purpose there are a number of known methods.

Lissajous' Figure Method.

For instance, at the Bureau of Standards a radio-frequency wavemeter was calibrated in terms of a standard tuning-fork by producing Lissajous' figures, from which the frequency ratios were determined (Hazon and Kenyon, Scientific Papers of the Bureau of Standards, No. 489). The chief limitation of this method is that ratios greater than about 15 : 1 introduce such complicated patterns that to recognise the ratio between the two frequencies which are compared is difficult, if not impossible.

Method of the Western Electric Co.

The Western Electric Company developed a slightly different method (Kipping "Electrical Communications," July, 1924). The principle of this method is briefly as follows: The motion of a particle described by $x = a \cos nt$, $y = b \cos (nt + \epsilon)$ is an ellipse. Now if $a = b$ and, further, if $\epsilon = \frac{\pi}{2}$, the ellipse becomes a circle. Now suppose $x = a \cos nt + b \cos pt$ and $y = a \sin nt$ and that p/n is integral, then it is readily seen that the path is a circle with a serrated edge. If the cathode-ray beam is subjected to forces as defined above, a pattern with serrated edges is produced. By counting the number of edges the frequency ratio is determined.

Rotating Ray Methods.

A valuable contribution was made by D. W. Dye, of the National Physical Laboratory, by developing his rotating ray method (Dye, *Proc. Phy. Soc.*, 1925, 37, 158). This method possesses great advantages and is particularly suitable for the purpose of setting a low radio-frequency to an exact value for purposes of calibration. Briefly, the rotating ray method consists in producing first a circular or elliptical time trace by means of two-phase voltage of low frequency. The radio-frequency is then caused to operate on the ray in one of three different ways. These are as follows :—

(1) A small voltage (about 20–30) at the radio-frequency is introduced into the steady anode voltage supply of the cathode-ray tube. The ray thus receives a radial vibratory displacement due to the radio-frequency at whatever position it may be in its circular or elliptical path at the lower frequency. This is due to the variation in velocity of the electrons forming the ray consequent upon the variation of the anode voltage.

(2) A small circular movement is given to the ray at the radio-frequency, whilst the larger circular or elliptical movement is provided by the lower frequency.

(3) A vibratory movement in a fixed direction is given by the radio-frequency, whilst the large circular or elliptical movement takes place at the audio-frequency.

Of these three methods the first one is not convenient in practice. One of the disadvantages of this method of superposition is that a rather high voltage at the radio-frequency is necessary to produce the requisite radial deflection, and a loss of definition occurs when the voltage reaches its minimum value. The radial movement permissible is also very limited.

The second method is the most convenient of the three in practice. The advantage of this method is the much smaller high-frequency voltage necessary as compared with the first method, and, further, the formation of a looped pattern renders counting easier. However, some disadvantages of this method will be referred to below.

The third method is suited more for the examination of waveform than for the comparison of frequencies.

Since the present article is concerned with the second method, the arrangement by which it is carried out is shown in Fig. 1. Here the low-frequency circular or elliptical motion of the cathode ray is produced by applying the low-frequency P.D's in quadrature at *ab* and *bc*. The high-frequency rotation of the cathode ray is produced by means of field coils F_1, F_2. These produce a magnetic deflection in a plane which can be rotated by turning the coils round the axis of the tube. The quadrature deflection at the high-frequency is produced by introducing the high-frequency voltage at *e* in the lead marked *c*. When the two frequencies are in simple ratio a looped pattern is produced, the loops being either inside or outside the low-frequency circular motion according as the two circular motions of the cathode ray are in the same or in opposite directions.

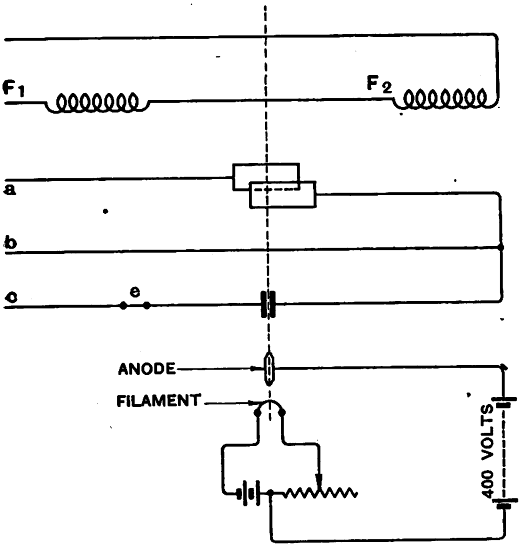


FIG. 1. *Cathode-ray tube arrangement.*

Two disadvantages are encountered when this method is put into practice. One is that it requires a special mounting of the oscillograph with the coils F_1, F_2 arranged so that they can be rotated around the axis of the cathode-ray tube for phase adjustments. The other is that, unlike in pure electrostatic deflection, considerable power is needed to produce sufficient magnetic deflection.

It appears, therefore, that a method of superimposing both the circular motions on the same two pairs of plates of the oscillograph without at the same time sacrificing convenience of independent adjustment of the amplitudes of the two circular motions is desirable. A number of arrangements were tried with this object in view. The circuit represented in Fig. 2 was found to be satisfactory. The oscillograms shown in Figs. 3 and 4 were produced with the help of this circuit, the ratio of the two frequencies compared being 1 : 6. The absolute values of the two frequencies were of the order of 3,000 cycles per second and 18,000 cycles per second. This circuit was found convenient in practice and allowed independent adjustment of amplitudes such that the high-frequency loops could be reduced to bright spots as was done by Dye (*loc. cit.*).

The action of the circuit may be explained as follows: Circuit *MNOQ*, containing a condenser C_1 and resistance R_1 in series, forms a phase-splitting device for the low frequency. Similarly, circuit *OPSQ*, containing the condenser C_2 and resistance R_2 in series, forms a phase-splitting device for the high frequency. The point *N* is connected to the common plates of the oscillograph.

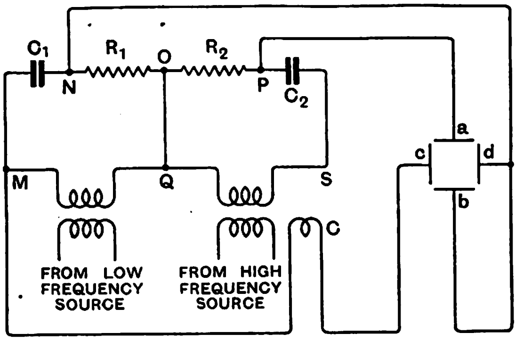


FIG 2. *Cathode-ray oscillograph plates.*

Since there is no coupling between the two circuits *MNOQ* and *OPSQ* because of the short-circuit *OQ*, the low-frequency current may be considered to circulate in the former circuit and the high-frequency current in the latter circuit.

Now considering P.D.s due to the low-frequency current, the P.D. between the oscillograph plates *a* and *b* is that between the points *N* and *P*, which is the same as that between the points *N* and *O*. The low-frequency P.D. between the oscillograph plates *c* and *d* is that between the points *M* and *N*. Since these two P.D.s are in quadrature the elliptical or circular motion due to the low-frequency P.D.s is produced.

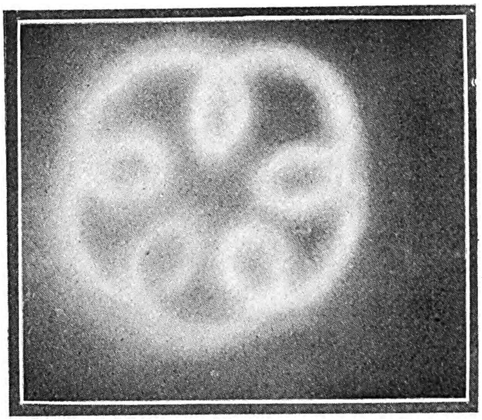


Fig 3.

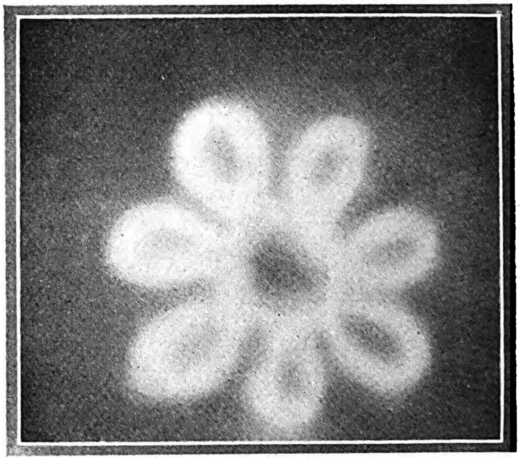


Fig. 4.

Now considering the P.D. due to the high-frequency current in the circuit *OPSQ*, the high-frequency P.D. between the plates *a* and *b* is that between the points *P* and *N*, which is the same as that between the points *P* and *O*. The high-frequency P.D. between the oscillograph plates *c* and *d* is that induced in the coupling coil *C* which is in quadrature with the P.D. across *PO*. Thus when the two frequencies are in simple ratio the patterns of Figs. 3 and 4 are produced.

Book Reviews.

AMATEUR RADIO VOCABULARY IN FIVE LANGUAGES. 217 pp. Published by "Radiokonstrukce," Prague.

This is published in Prague primarily for Czech readers and those interested in publications in the Czech language. The five languages are English, Czech, Esperanto, German, and French, and any radio word in any one of these languages can be turned up at once and its equivalent found in the other four. Although it is far from perfect, it should prove very useful to any English reader who wishes to read radio literature in any of the other languages. The English portion is due to Mr. W. H. Matthews, of Chadwell Heath, but we suspect that he was not given a chance to correct the proofs, for we note some strange alleged English, of which the following are samples: What is really a H.T. mains supply unit is translated "b'eliminator, power suply, power pack, voltage suply"; litz is "aerial lace." Bel clapper, wawemeter wawetrap and so on are obvious slips which would not worry an English reader.

DER SPRECHENDE FILM (The speaking film). By Dénes von Mihály, pp. vi+131, with 99 Figs. M. Krayn, Berlin.

This book gives a critical description of the various methods of recording sound on photographic film and subsequently reproducing the sound from the film. It is written in a popular descriptive style and is entirely non-mathematical. After an historical introduction the fundamental acoustic and electro-optical phenomena are described; then follows a description of kinematographic apparatus, and finally a descriptive review of the various methods which have been developed, from the early experiments of Ruhmer to the modern Triergon and Movietone systems.

G. W. O. H.

The Study of Signal Fading.

An Account of the Work of the Peterborough Radio Research Station of the Department of Scientific and Industrial Research.

Paper read by Prof. E. V. Appleton, F.R.S., before the Wireless Section, I.E.E., on 4th April, 1928.

ABSTRACT.

THE paper deals with work on the subject of fading done at the Peterborough Station of the D.S.I.R. This station, which was formerly a Post Office receiving station, was taken over on September, 1925, for experiments in connection with the work of the Propagation of Waves Committee of the Radio Research Board.

THE NATURE OF THE PROBLEM OF SIGNAL VARIATIONS.

The author first refers to the well-known fact of fading at 100–150 miles distance. Galvanometric methods of observation, however, show small signal variations, undetected in telephones, at much shorter distances. An advantage of working at such distances is that there is a strong ground wave of fairly constant intensity which may be used as a reference.

In considering the general problem of the simultaneous reception of ground waves and one or more sets of downcoming waves. Fig. 1* is given, showing O as the site of a receiving station at which a ground wave (with electric and magnetic amplitude vectors E_0 and H_0 respectively) and downcoming waves, incident at angles ϕ_1, ϕ_2, etc., are received. The downcoming wave incident at an angle ϕ_1 may be resolved into its two components, one (E_1, H_1) with electric vector in the plane of propagation and the other (E'_1, H'_1) with electric vector perpendicular to this plane. The corresponding vectors for the wave incident at an angle ϕ_2 are (E_2, H_2) and (E'_2, H'_2) and so on. For the wavelengths we are considering we can regard the ground as approximating to a perfect conductor, so that the downcoming waves are reflected there with but little loss of amplitude.

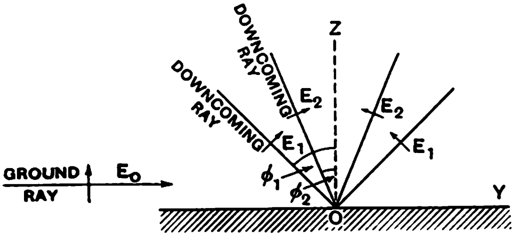


Fig. 1.—*The X axis is at right angles to the paper.*

The electric and magnetic forces at O may therefore be written

$$\left.\begin{aligned} &E_x=0,\ H_x=H_0\sin\omega t+2H_1\sin(\omega t+\theta_1)\\ &\qquad\qquad +2H_2\sin(\omega t+\theta_2)+\ldots\\ &E_y=0,\ H_y=2H'_1\cos\phi_1\sin(\omega t+\theta'_1)\\ &\qquad\qquad +2H'_2\cos\phi_2\sin(\omega t+\theta'_2)+\ldots\\ &E_z=E_0\sin\omega t+2E_1\sin\phi_1\sin(\omega t+\phi_1)\\ &\qquad\qquad +2E_2\sin\phi_2\,.\,\sin(\omega t+\theta_2)+\ldots\\ &\qquad\qquad \text{and } H_z=0 \end{aligned}\right\}\quad(1)$$

where ω is the angular frequency of the waves and θ_1, θ'_1, θ_2, θ'_2, etc., represent phase differences between the ground wave and the various components of the downcoming waves.

DETERMINATION OF CHARACTERISTICS OF DOWNCOMING WAVES.

In the simple case of a loop in the plane of propagation, as in Fig. 2, the magnetic force H_x linked with the loop may be written

$$H_x=H_0\sin\omega\left(t-\frac{a}{c}\right)+2H_1\sin\omega\left(t-\frac{a'}{c}\right).\ (2)$$

where a and a' represent the optical paths TO and TBO respectively, and c is the velocity.

This may be re-written

$$H_x=H_0\sin\omega t'+2H_1\sin(\omega t'+\theta),\quad ..\ (3a)$$

---

* The author's original figure numbers and equation numbers are adhered to throughout this abstract.

where $\theta = -\frac{\omega D}{c} = -\frac{2\pi D}{\lambda}$,

λ being the wavelength, while $D = a' - a$ and $t' = t - a/c$.

If this E.M.F. is amplified linearly and rectified by a detector having a "square law" characteristic, the mean signal current

$$\bar{i} = A(H_0^2 + 4H_1^2 + 4H_0H_1\cos\theta) \quad .. \quad (4)$$

The fact of night variations in such a loop indicates that H_1 or $\cos\theta$ or both must be changing, assuming H_0 to be approximately constant. The ratio of day and night signals may thus be written

$$\frac{\bar{i}_N}{\bar{i}_D} = 1 + 4\left(\frac{H_1}{H_0}\right)^2 + 4\frac{H_1}{H_0}\cos\theta \quad .. \quad .. \quad (5)$$

The effect of changing the wavelength of the transmitter is then considered. It is shown that for slow diminution of the wavelength the signal current $\bar{i}_N$ passes through a maximum and a minimum value. The number, n, of signal maxima (or minima) encountered in changing the wavelength from λ_1 to λ_2 is

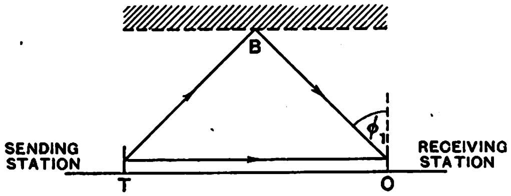


Fig. 2

$$n = \frac{\theta_1 - \theta_2}{2\pi},$$

where $\theta_1 = 2\pi D/\lambda_1$ and $\theta_2 = 2\pi D/\lambda_2$,

so that $$n = \frac{D}{\lambda_1} - \frac{D}{\lambda_2} \quad .. \quad .. \quad .. \quad .. \quad (6)$$

A signal maximum M, artificially produced by change of wavelength, indicates that θ is 0, 2π, 4π, etc.; a minimum m indicates that it is π, 3π, 5π, etc.

Thus from (5)

$$\frac{2H_1}{H_0} = \frac{\sqrt{(M/m)} - 1}{\sqrt{(M/m)} + 1} \quad .. \quad (7)$$

Almost similar considerations apply to the determination of ϕ_1, the angle of incidence. Study of signal variations on an aerial set and on a loop set simultaneously permit the determination of $\bar{i}_N/\bar{i}_D$ for both receivers. If signal maxima and minima due to wavelength change are recorded either simultaneously or in rapid succession on both loop and aerial sets, by using only measurements at maximum and minimum values, we get (7) for the loop, and for the aerial

$$\frac{2E_1\sin\phi_1}{E_0} = \left[\frac{\sqrt{(M/m - 1)}}{\sqrt{(M/m + 1)}}\right]_{\text{Aerial}} \quad .. \quad (9)$$

Hence, since E_1/E_0 is equal to H_1/H_0, we get

$$\sin\phi = \frac{\left[\frac{\sqrt{(M/m - 1}}{\sqrt{(M/m) + 1}}\right]_{\text{Aerial}}}{\left[\frac{\sqrt{(M/m) - 1}}{\sqrt{(M/m) + 1)}}\right]_{\text{Loop}}} \quad .. \quad .. \quad (10)$$

In this way ϕ_1 may be found.

By using the method of wavelength change, attention may be confined to maximum and minimum values, permitting solutions not obtainable by simple intensity measurements. The method does not require a knowledge of the strength of the ground ray, and is a sensitive test of the presence of downcoming waves, especially when the latter are weak.

Complete records of variations in the downcoming waves could be obtained by record of the interference maxima and minima on various loop and aerial systems, but the apparatus would become somewhat complicated. It is thus desirable to study the temporal variations of the intensities of the two components of the downcoming wave.

To receive signals due to the normally polarised component E_1, we may use a loop and aerial combination possessing a polar reception diagram of cardioid form. In this case, if the assembly is adjusted to cut out the ground ray during the daytime, only the downcoming wave is received at night and its intensity variations may be studied directly. To receive signals due to the abnormally polarised component H'_1, a vertical loop at right angles to the plane of propagation is used.

EXPERIMENTAL DETAILS.

The essentials of the receiving apparatus are shown in Fig. 4, the apparatus consisting of a high frequency amplifier followed by a simple rectifier and galvanometer. For wavelength-change experiments, resistance capacity amplifiers with low capacity valves have been used. For observations on constant wavelength, neutrodyne amplifiers have been found satisfactory. For the rectifier a crystal has been used, and, more recently, the valve voltmeter arrangement shown in Fig. 4, which is a Wheatstone bridge assembly, balanced when no signal is being received.

For recording natural signal variations due to a constant-wavelength transmission, a Pye galvanometer with a 5-second period has been used, together with a Cambridge drum camera. For recording signals received during a wavelength change, which is usually made to take place in about 5 seconds, a Cambridge Einthoven galvanometer has been employed.

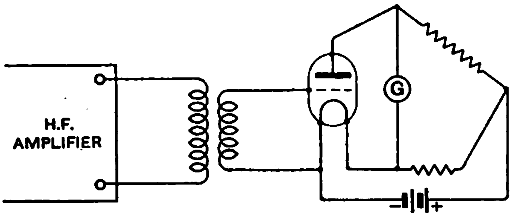


Fig. 4.

SOME EXPERIMENTAL RESULTS AND CONCLUSIONS.

Study of downcoming waves by the methods described has led to the following general conclusions.

(1) Fading is due to the effects of variable rays deviated by the upper atmosphere. The fact of interference maxima and minima being obtained when the wavelength is changed indicates the presence of two waves, one of which must be the ground wave. The fact that interference maxima are greater when receiving on a loop aerial indicates that one set of waves reaches the ground at an angle of incidence less than $\frac{1}{2}\pi$, *i.e.*, comes down from above.

(2) The equivalent height of the ionised layer may be determined by a simple calculation from the value of D, the path difference between ground and atmospheric waves, or from ϕ_1, the angle of incidence. Measurements made during the dark hours show that for most nights, after sunset, the height gradually increases, reaching its maximum value about an hour before sunrise, when a somewhat rapid change takes place to the lower daytime value. During a normal night the height may vary from 90 to 130 km., but, on occasions, in winter, heights of an entirely different magnitude, such as 250 to 350 km., have been measured during the three hours before dawn.

(3) Variations may occur due to changes in (*a*) angle of incidence, (*b*) intensity, (*c*) phase, (*d*) polarisation of the downcoming waves. By simultaneous study of the signals on a vertical aerial and on the suppressed ground ray system, it is possible to show that changes in intensity of the downcoming waves (" intensity fading ") are more frequent than changes in the phase difference between ground and downcoming rays (" phase fading "). It is also concluded that rotation of the plane of polarisation is not responsible in any marked degree for signal fading on these wavelengths, and that on the whole intensity variations and, to a lesser degree, phase variations are the chief causes of signal fading.

(4) From experiments on the polarisation of the downcoming waves, it is concluded that it may be described as approximately circularly polarised with a left-hand rotation. This is possibly due to the influence of the earth's magnetic field, but a critical test would be to repeat the experiments in the Southern Hemisphere, when right-hand rotation would be looked for.

OBSERVATIONS ON THE OCCASION OF THE SOLAR ECLIPSE, 29TH JUNE, 1927.

The observations made on the occasion of last year's eclipse are quoted as typical of the kind of records obtained. These were made on special transmissions arranged by the B.B.C.:

(i) Transmissions of an unmodulated carrier wave, the wavelength of which could be changed continuously through a small range with but small variation of amplitude. Such transmissions took place from the Newcastle and Birmingham B.B.C. stations, and were used for the special measurements of the type described above.

(ii) Transmissions of a carrier wave of constant amplitude, unmodulated except for the announcement of time signals. The signal variations at various distances were studied by observers using galvanometric methods. Such transmissions took place from the London and Manchester B.B.C. stations.

As the region of totality in the ionised layer differed from that on the ground, observations in the region of ground totality were made at Liverpool on the Newcastle transmissions, and in the region of layer totality at Peterborough on the Birmingham transmission.

Observations on the transmissions of type (ii) were made at St. Albans, Nottingham, Peterborough, Newcastle-on-Tyne, Giggleswick and Aberdeen.

EXPERIMENTAL RESULTS.

(a) *Observations at Peterborough on the Birmingham Transmissions.*

Using the wavelength-change method the following quantities were determined:

(1) H_1/H_0, deduced from the amplitude of the "fringes" recorded when the loop aerial was used.

(2) Path difference D.

(3) Angle of incidence ϕ_1 of downcoming waves, deduced from the relative amplitudes of the "fringes" recorded using loop and vertical aerial in rapid succession.

Check observations were made on the days before and after the eclipse, and as the eclipse was so soon after sunrise, observations began each day at 2 a.m. G.M.T. so as to cover the period of normal sunrise effects.

Fig. 6, for the morning of the eclipse, shows he variation of intensity of the downcoming ray as a fraction of the ground ray intensity. Normal daytime conditions had been reached before the effects of the eclipse were noticeable. At the time of the large increase due to the eclipse, the observations show that the equivalent path difference between ground and atmospheric waves had increased, while the angle of incidence of the downcoming waves at the ground had been reduced. The first of these effects is illustrated in Fig. 7, in which $\delta n/\delta\lambda$, the number of fringes per metre wavelength change, a quantity which is proportional to the path difference (D) between ground and atmospheric rays, is plotted as a function of the time. The increase in the value of $\delta n/\delta\lambda$ caused by the eclipse is equal to an increase in the equivalent height of the layer from 75 to 94 km. The decrease in the angle of incidence at which the downcoming waves reach the ground also indicates an increase in the height of the stratum responsible for deviating the waves. We therefore conclude that the increased intensity of the downcoming ray was due to the removal of ionisation in the lower layers of the atmosphere, together with an increase in the height at which the waves were turned back. The large "fringes" recorded during the period of the eclipse effect were, however, smooth and therefore similar to those recorded about 3.45 a.m. rather than to those representative of night-time conditions, when "secondaries" are almost always present. We must therefore regard the effect of the eclipse as only a partial return to proper night-time conditions.

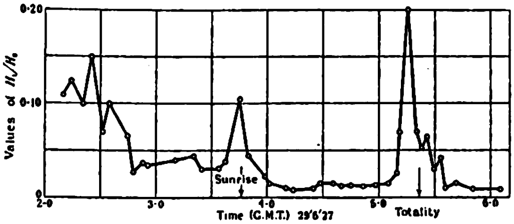


Fig. 6.

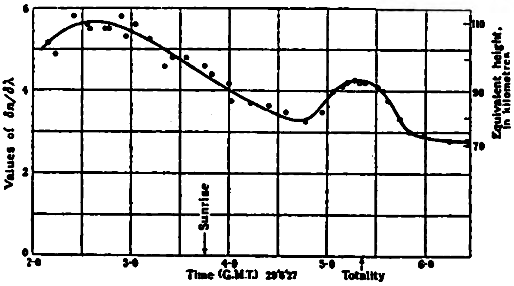


Fig. 7.

Examples of the signal maxima and minima obtained before, during, and after the eclipse effect are shown in Fig. 8. The records show the marked increase in the intensity of the downcoming ray at totality.

(b) *Observations at Liverpool on the Newcastle Transmissions.*

During the middle of the eclipse period these observations were rendered quite impossible by interference from a neighbouring amateur transmitting station (6NI), so that no observations could be made during the critical period of 4.50 a.m. to 5.25 a.m. on 29th June. The readings that were obtained at the beginning and end of the eclipse period entirely confirm the Peterborough results, but the interference prevented the comparison of the eclipse effects in the regions of layer totality and ground totality respectively.

(c) *Observations on the constant wavelength transmissions from London and Manchester.*

As already stated, these observations were made at St. Albans, Nottingham, Peterborough, Newcastle, Giggleswick and Aberdeen. Readings of rectified signal current were taken every 10 seconds throughout each alternate 10 minutes during the period of the transmissions, except during the eclipse when readings were taken every 5 seconds continuously. The results obtained confirm the variations in downcoming ray intensity noted at Peterborough.

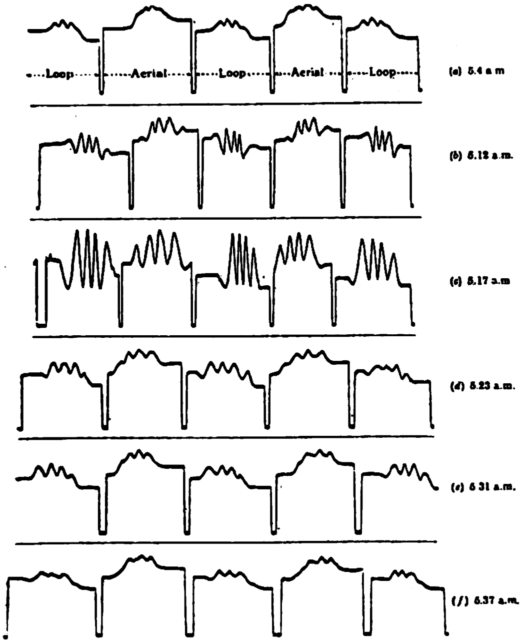


Fig. 8.—*Signal variations received alternately on loop and aerial, beginning on loop.*

Two particular cases most simply illustrate the main effect.

At Nottingham a strong ground ray was received and the downward ray was evidenced by small variations about a constant mean value. Fig. 9 shows the mean departure of signal from daytime value, which gives an inferior limit for the downcoming ray intensity relative to that of the ground ray, for the eclipse morning and for the same period on 1st July.

It is to be noted that, as in the case of the Peterborough measurements, the greatest amplitude of downcoming ray was detected before totality.

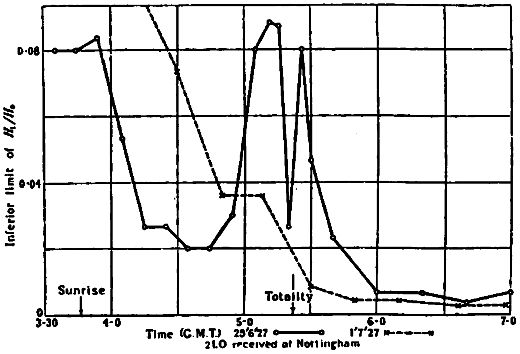


Fig. 9.

In the case of observations at Giggleswick on 2LO, the reception was almost solely on indirect ray or rays, so that signal-current readings may be taken as indicating the strength of downcoming waves. These are shown in Fig. 10. A similar increase of signal intensity was reported at the more distant station of Aberdeen, where the normal daytime signal is negligible.

At Giggleswick the maximum of downcoming ray was just about the time of layer totality, while at Aberdeen it was at 5.29, that is 7 or 8 minutes afterwards. Another observer at a distant station in Pembrokeshire found maximum signal intensity at 5.27 a.m.

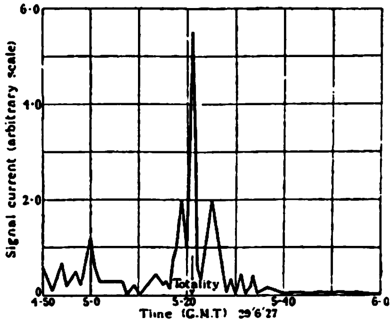


Fig. 10.

Discussion of Eclipse Results.

The observations show that the eclipse produced a very definite effect on the properties of the layer responsible for deflecting waves of 300–400m. back to the earth. The most striking feature was the large increase in intensity of the downcoming ray at both near and at distant stations. This is ascribed partly to increase in height of the stratum responsible and partly to the rapid removal of ionisation in the lower layer of the atmosphere consequent on the removal of the solar ionising agents. The results suggest that the more southerly stations experienced the maximum influence a little earlier than the northern stations.

A striking feature was the short time that the eclipse effect lasted, the period varying from 20 to 50 minutes at different stations, while the total time taken for the moon's shadow to pass across the sun was nearly 2 hours. This means that a large fraction of the sun's radiation may be cut off before the effect can be detected by wireless methods.

DISCUSSION.

In opening the discussion which followed the paper, **Mr. T. L. Eckersley** congratulated the author on the very interesting work which represented the maximum return for the energy expended. He would be interested to have a comparison of layer height, as determined by fringes and as determined by the angle of incidence. The methods suggested one downcoming ray, but observations showed that the downcoming ray was very composite, and he thought that this point should be cleared. Fading was intrinsic to the downward ray as was confirmed by short-wave work. Comparison of fading of short waves on horizontal and on vertical aerials were suggestive of rotation of the electric vector. On short waves there was also more trace of right-hand rotation in the polarisation than of the left-hand rotation suggested by the author. Observations had actually been made in which this varied in certain cases with the season. Could the author from his measurements give a figure for the height of the layer in daytime ?

Prof. G. W. O. Howe expressed great appreciation of the author's work and of his energy and enthusiasm. The paper pointed to difficulties still remaining. There was nothing to indicate the causes of the phenomena. What was happening to cause changes in the intensity of the downcoming wave ? The very high rise at the eclipse time did not seem as if the night effect was only partially restored.

Dr. E. H. Rayner said the paper marked the beginning of radio measurements applied to upper air measurements, and emphasised the importance of the eclipse observations in these problems. He showed a model of the eclipse effect, illustrating the distribution of totality, and outlined the work of the Committee which had been dealing with the arrangements for the radio measurements. Such observations should form part of future eclipse observations.

Capt. P. P. Eckersley said that fading limited the service area of broadcasting stations, and the B.B.C. gave 100 miles as a figure beyond which fading might be expected. Hilly country appeared to have some effect on this, as at Carnarvon, for example, 5GB faded badly, but in Norfolk at 145 miles from 5GB he had found no trace of fading. Was it possible to get an aerial to receive the direct ray only eliminating the indirect ray ? He was interested in the study of telephony over long distances where only the indirect ray was available. Did the author consider that there was differential fading as between side bands and carrier ? Such fading had been noted in work on two broadcast transmitters working on the same wavelength.

Mr. J. Hollingworth referred to the simplicity of the apparatus used. As the effects were different on different wavelengths, the author should specify that this paper was limited to certain wavelengths. With reference to the direction of the rotation of polarisation, he used both left hand and right hand, and found that these sometimes changed during the day. The disadvantage of the wavelength change method was the large ether band which it occupied, especially on longer waves, since the percentage change varied with wavelength. He hoped shortly, by co-operation with the Post Office, to observe on a 10 per cent. change on 8,000 metres.

Mr. R. H. Barfield said he had been working on parallel lines, and had got confirmation of the author's results by independent methods. Three methods of measuring the angle of incidence had been used : (*a*) the forward tilt, measured by a rotating Hertzian rod, (*b*) the tilt of the magnetic field measured by a rotating coil which could also be rotated about a horizontal axis, (*c*) a method of comparing the magnetic and electric fields. All angles gave heights approximately in agreement with the author.

Col. H. P. T. Lefroy suggested the distance of two layers, one higher and going round with the earth, and the lower and more dense layer, being a function of sunlight, following like the tail of a comet.

Mr. G. H. Munro referred to direction-finding measurements (at the time of the eclipse) at Giggleswick, Ditton Park and Bristol. The results confirmed the author's experiments, directions becoming very unstable with the eclipse. Intensity measurements also gave results similar to those of the author.

Prof. Appleton replied to several of the points raised in the discussion, especially with reference to the remarks of Mr. T. L. Eckersley.

On the motion of the Chairman (Lt.-Col. A. G. Lee, O.B.E., M.C.) the author was cordially thanked for his paper.

A Short Survey of Some Methods of Radio Signal Measurement.

By *K. Sreenivasan, B.Sc.*

(Concluded from page 210 *of April issue.)*

4. *Baümler's Method.**—At the Telegraphentechnische Reichsamt in Berlin, Baümler developed apparatus for measuring the field strength of Transatlantic stations like Marion, Tuckerton, etc. The observations recorded are those of a complete year with hour to hour readings throughout the twenty-four hours of the day. These observations form perhaps the most continuous and extended investigation on the variation of field strength of long-distance radio stations. Baümler's conclusions acquire additional weight since he employs an objective method free from personal equation as with the aural method.

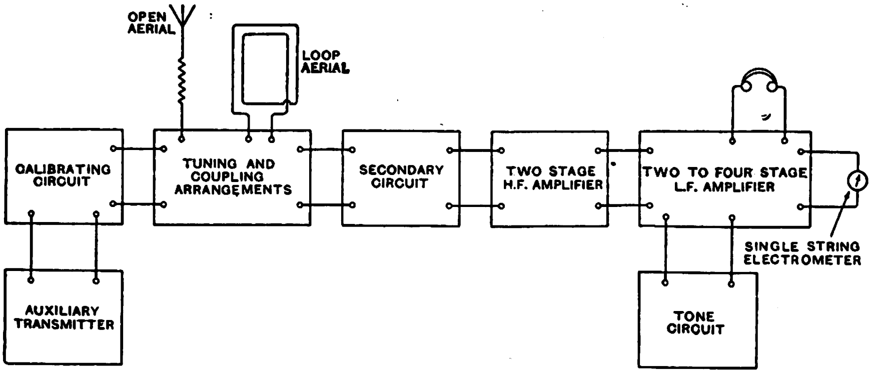


Fig. 5.—*Receiving arrangement employed in Germany by Baümler, 1923-1924, for reception of Tuckerton.*

Method of Measurement (Fig. 5).—For measurement, an open antenna and a loop aerial are used. The receiving apparatus, in addition to the receiving aerials, consists of a small coupling coil, a secondary circuit, a two-stage high-frequency amplifier, a two to four-stage low-frequency amplifier, a heterodyne circuit, and an auxiliary transmitter with a measuring circuit. The amplifiers are all of the transformer coupled type. In the primary winding of the transformer in the last stage of the low-frequency amplifier, a telephone is inserted for detecting the station to be measured. In the secondary winding of the same transformer is a single string electrometer which is used for measurement. The thread of the electrometer follows accurately the code signals of the station under observation.

Method for Obtaining Small H.F. Voltages.—The auxiliary transmitter consists of a triode oscillator and two aperiodic or untuned coils, *P* and *Q*, coupled to the measuring circuit over a calibrated mutual inductance *M*. By this means small known H.F. voltages are introduced into the receiving system for purposes of comparison with the incoming signal. The calibrated mutual inductance can be replaced by a potentiometer arrangement across the secondary of a small radio frequency current transformer. Arrangements with either of these two methods permit the measurement of antenna currents up to 10^{-7} ampere.

---

* 1. M. Baümler, "Recent investigations on the propagation of Electromagnetic Waves," *Proc. Inst. Rad. Engs.*, Vol. 13, No. 1, 1925, p. 5.

2. G. Anders, "Quantitative Emphangsmessungen in der Funkentelegraphie," *Elektrische Nachrichten Technik*, Vol. 2, No. 12, 1925, p. 416.

Undesirable inductive couplings are avoided by winding all H.F. coils as differential coils; stray capacitative couplings are kept down by suitably arranging the circuits. The residual inductive and capacitative couplings are avoided by placing the individual elements of the apparatus in separate boxes lined with copper plate. The shielding being as thorough as possible, measurements can be carried on at any wavelength without any lurking doubt about stray electromagnetic disturbances.

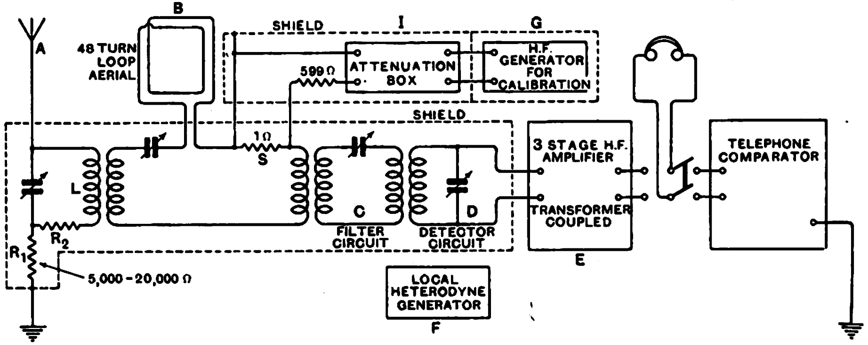


Fig. 6.—*Circuit of Dr. L. W. Austin, used at Washington for long-wave reception.*

The receiving arrangements are adjusted to give deflections on the electrometer directly proportional to the aerial current due to the incoming signal. Then coil Q is inserted in the auxiliary transmitter and the couplings in it are adjusted till the electrometer is brought to the same deflection as before, the receiving arrangement remaining unchanged throughout. The arrangement, besides being objective, is remarkably independent of atmospheric disturbances. The signal to be measured is easily distinguished from these disturbances.

5. *Austin's Method.**—The method used by Dr. L. W. Austin some time ago and the results obtained by him are of great interest.

The apparatus used by Dr. Austin has some notable departures from the more usual practice. With this set, he has measured practically all the high power long-wave stations in the world.

For measurement, both an open antenna *A* and a coil aerial *B* are used (Fig. 6). *C* is a filter circuit for minimising troublesome interferences. *D* is the detector, and *E* a three-stage radio frequency amplifier, adjusted to prevent self-oscillation. *F* is a heterodyne oscillator to produce any desired beat note in the telephones.

Calibration of the receiving set is effected by the triode generator *G*. The current in the oscillating circuit, measured in the usual way by a thermojunction and galvanometer, passes through an attenuation box *I* and a one-ohm resistance *S* across the loop aerial. Thus, an accurately known, easily adjustable small radio frequency E.M.F. is injected into the receiving aerial—exactly the same arrangement used by Messrs. Englund, Bown, and Friis.

The peculiarity of the method consists (*a*) in making all measurements at the same pitch of sound in the telephones, and (*b*) in the arrangement to measure the telephone current. The telephone current measuring device (Fig. 7) consists of a tuning fork generator of 1,000 cycles, which is measured by a thermo-galvanometer and then passed through a potential divider arrangement. By this means any known 1,000 cycle E.M.F. can be put on the telephones.

Whatever be the frequency of the incoming signal, the heterodyne *F* is always adjusted to give a beat frequency equal to that of the telephone comparator. Intensity of the telephone note due to the comparator is made equal to that due to the signal by adjustment of the potential divider and by switching the telephones rapidly from the receiver to the telephone comparator.

---

* L. W. Austin and E. B. Judson, "Method of Measuring Radio Signals used at the Radio Physical Laboratory, Bureau of Standards, Washington," *Proc. Inst. Radio Engs*, Vol. 12, No. 5, Oct. 1924, pp. 521-533.

With this arrangement, Dr. Austin has covered very long distances.* From San Diego in California, where Austin conducted his experiments, Cavite in the Philippine Islands is 11,000 km., with a time difference of 8 hours, while the high power station Malabar in Java is 14,700 km., with a time difference of 9 hours. Malabar has at San Diego a field strength of 4.02 μv./m., and Cavite a field strength of 2.04 μv./m. The corresponding calculated values on the basis of the Austin-Cohen attenuation factor are 1.83 μv./m. and 0.69 μv./m.

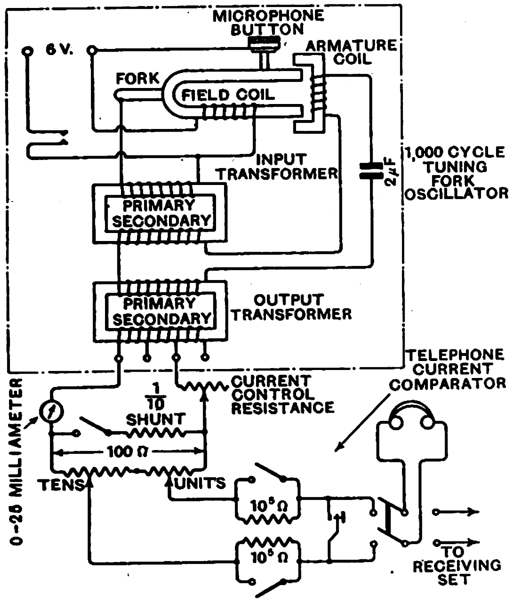


Fig. 7.—*Telephone current measuring device employed by Dr. L. W. Austin.*

These values were about the lowest measured up to that time.

The Marconi Company Method.†—During 1922–23, Messrs. Round, T. L. Eckersley. Tremellen and Lunnon, of the Marconi research staff, successfully carried out a most ambitiously planned expedition to study the complicated phenomena attending electro-magnetic wave propagation over long distances and to secure data necessary to establish communication between any two given places on the earth. The expedition, starting from England, went to North America, through the Panama Canal to New Zealand, thence along the South and the West coasts of Australia to Ceylon; and thence through the Suez Canal and the Mediterranean round Spain back to England. The conclusions arrived at from the huge mass of data collected during this big expedition throw a flood of light on the varied and complex factors affecting radio wave propagation.

*Apparatus and Method of Measurement.**—The receiving aerial is tuned to the incoming signal frequency; coupled to the aerial circuit is a tuned circuit followed by an amplifier and a separate heterodyne. The signals from the latter are introduced in the last stage of the amplifier. To prevent stray inductive and capacitative E.M.F.s, and also to avoid direct pick up of the signal by the amplifier, the whole apparatus is well screened by being enclosed in a metal box.

To determine the field strength, *i.e.*, primarily, to measure the E.M.F. induced in the aerial by the signal, an auxiliary transmitter and a dummy aerial are employed. The electrical constants of the dummy or non-radiating aerial are made as nearly the same as those of the actual receiving aerial.

The auxiliary transmitter is in three mutually screened compartments of a well shielded box. In the first compartment is a triode oscillator coupled to an intermediate circuit, the current in which is measured by the potentiometer slide-back method due to Captain Round.† The intermediate circuit is in the second compartment.

In the third compartment are two sets of mutual inductances which are calibrated over a reasonably large range of frequencies.

---

* 1. L. W. Austin, *Proc. Inst. Radio Engs.*, Vol. 12, 1924, p. 521.

2. L. W. Austin, *Proc. Inst. Radio Engs.*, Vol. 13, No. 2, 1925, p. 151.

3. L. W. Austin, *Proc. Inst. Radio Engs.*, Vol. 13, No. 3, June 1925, p. 283.

† Report on Measurements made on Signal Strength at Great Distances during 1922 and 1923 by an Expedition sent to Australia: by Round, Eckersley, Tremellen, and Lunnon. — *Jour. Inst. Elec. Engs.*

* 1. *Ibid.*

2. "Discussion on Long distance Transmission," *Jour. Inst. Elec. Engs.*, 1921, Vol. 59, p.677.

† Round, "Valve in Wireless Measurements," *Rad. Rev.*, Vol. II, June 1921, pp. 303-7.

The mutual capacity coupling between the various coils was found to be negligible.

It is through this mutual inductance that the intermediate circuit of the auxiliary transmitter is coupled to the common part of the receiving and dummy aerial circuits. Knowing the value of M used, the frequency of the signal and the current in the intermediate circuit, the voltage induced in the dummy aerial is known. By proper adjustment, the artificial signal is made equal to the incoming signal with a pair of telephones; then from the known constants of the non-radiating aerial, the field strength is calculated.

There are a few points of interest in this apparatus :—

1. The method being subjective on account of the use of telephones to ascertain equality of the local and incoming signals, errors due to the observer and to the inherent defects of the telephone are inevitable.
2. As the authors have pointed out, the artificial signals in the dummy aerial are not in the same condition as the incoming signals on the receiving aerial as regards jamming and atmospheric disturbances.
3. Under the best conditions, it is difficult to secure identity, or at least even approximate equality, between the constants of the two aerials. For the above two reasons, the authors have whenever possible dispensed with the dummy aerial.

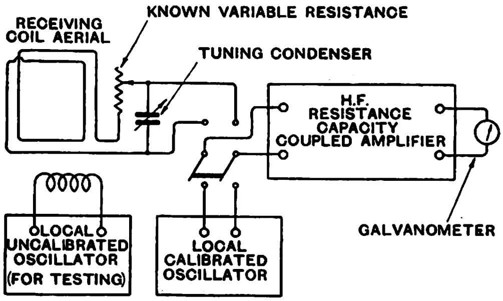

RECEIVING COIL AERIAL
KNOWN VARIABLE RESISTANCE
TUNING CONDENSER
H.F. RESISTANCE CAPACITY COUPLED AMPLIFIER
GALVANOMETER
LOCAL UNCALIBRATED OSCILLATOR (FOR TESTING)
LOCAL CALIBRATED OSCILLATOR

Fig. 8.—*General scheme of connections in the N.P.L method,* 1925.

4. Doubts have not infrequently been expressed with regard to precision in the measurement of radio frequency voltages by the slide-back method.* It appears as though considerable experience and practice are necessary to secure a fair degree of accuracy by this method.
5. To avoid direct pick up by the amplifier and to prevent stray inductive and capacitative E.M.F.s from getting into the receiving apparatus, efficient and elaborate screening arrangements are necessary.

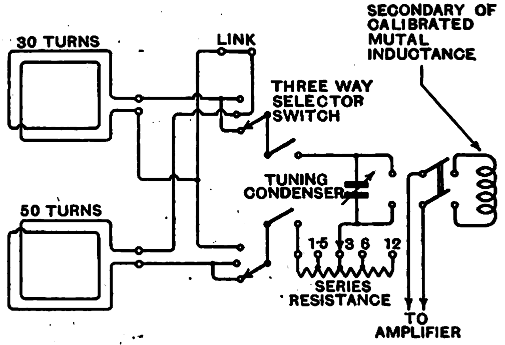


Fig. 9.—*Aerial and tuning circuits of the N.P.L. method.*

*The N.P.L. Method.**—About the year 1922, Mr. J. Hollingworth set up at the National Physical Laboratory measuring apparatus primarily to determine at Teddington the field strength of the U.R.S.I. signals. The arrangement has certain features distinguishing it from the others.

The aerial consists of a loop of 80 turns on a 5 ft. square frame with a three-way switch, by which 30, 50 or 80 turns can be brought into the circuit. Although the E.M.F. induced in a coil aerial of this kind is smaller than in an open aerial, the constants of the coil can be determined more accurately and they remain far steadier. There is the question of portability also, in cases where the apparatus has to be shifted from place to place. Fig. 9 shows the switching arrangements and the tuning condensers and series resistance, while Fig. 8 gives the general scheme of connections.

The incoming signal from the station under question is tuned in by the variable air condenser across the coil; the voltage across the condenser is then applied across the grid and filament of the first triode of a resistance capacity coupled amplifier

---

* E. B. Moullin, *Jour. Inst. Elec. Engs.*, 1923, Vol. 61, p. 295.

* *J.I.E.E.*, Vol. 61, No. 517, April 1923, p. 501.

(see Fig. 10). There are no low-frequency stages, and for purposes of listening in a separate heterodyne is used. For wavelengths greater than 2.5 km. this type of amplifier has several advantages :—

(*a*) Larger effective wavelength range as compared with the transformer type.

(*b*) The absence of any necessity to screen the amplifier since there are no coils to be affected inductively by external fields.

(*c*) Stability of working over a large range of frequencies.

It is essential that the amplifier should be adjusted to work well away from regeneration, though this may involve a slight lowering of the amplification factor.

In the anode circuit of the last stage of the amplifier there is a sensitive galvanometer ; a micro-ammeter in the case of special transmission or a string galvanometer with routine transmission. The normal anode current is balanced by an accumulator and potentiometer, so that ordinarily the galvanometer reads zero. When the signals come in, the grid of the last tube gets polarised, causing a diminution in the anode current. This is indicated as a deflection in the galvanometer. If routine transmission is received on a string galvanometer, the deflections will be in accordance with the dots and dashes composing the signal.

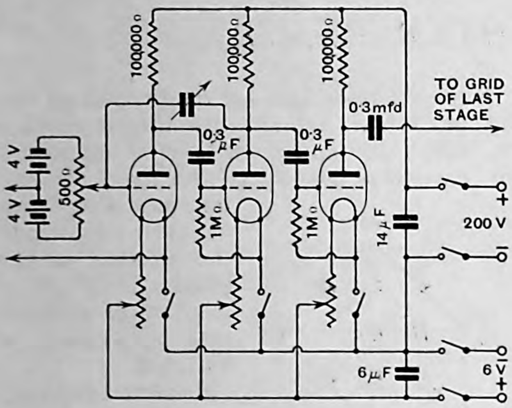


Fig. 10.—*Circuit of the high-frequency amplifier used in N.P.L. measurements,* 1925.

To determine primarily the E.M.F. induced in the coil, and from that deduce the field intensity, the coil is switched off from the amplifier and an adjustable known E.M.F. from the secondary of a calibrated mutual inductance belonging to a local oscillator is put on. By impressing varying voltages, the respective galvanometer deflections give the calibration curve of the amplifier. From this curve, the voltage corresponding to the signal is read off.

The local oscillator has several interesting features. Ordinarily a few turns of the main oscillating inductance form the primary, well screened from the rest of the oscillating inductance. In this apparatus, the whole of the oscillating inductance forms the primary of the mutual inductance and screening is avoided. Assumptions of any sort and suspicions regarding stray capacity coupling are entirely avoided by determining the value of the mutual inductance under normal working conditions. The mutual inductance has an untuned or aperiodic secondary, thus requiring the measurement of the high-frequency resistance of the receiving circuit for every measurement. This is effected as follows :—

A multi-way switch fitted in the coil circuit introduces into the oscillating circuit a series of known resistances. Deflections on the galvanometer due to a local or incoming signal are noted for all the positions of the switch. The corresponding voltages are then measured by the local calibrating circuit and the effective resistance calculated in the usual way. The measurement of high-frequency resistance, although a complication, acts as an effective check on the observations and avoids assumptions of uncertain accuracy. From this point of view, it is really an advantage.

Let D = field strength of the incoming signal.
n = number of turns in the coil.
a = area of a single turn.
L = inductance of receiving aerial.
R = effective resistance of receiving circuit.

E.M.F. induced in the coil due to the incoming signal $= \dfrac{2\pi an}{\lambda} D.$

Current in the coil $= \dfrac{2\pi anD}{R\lambda}$.

Voltage across the tuning condenser at resonance $= \frac{2\pi anD}{R\lambda} \sqrt{R^2+\omega^2L^2}$

$$\simeq \frac{2\pi anD\omega L}{R\lambda}.$$

If the calibrated oscillator is adjusted to give the same deflection as the incoming signal, then resonance volts

= volts applied to amplifier by the secondary of the calibrated mutual inductance,

i.e., $\frac{2\pi an\, D\omega L}{R\lambda} = \omega MI_0$, where I_0 is the current in the primary of the calibrated mutual inductance M.

$$\therefore \quad D = \frac{M\lambda}{2\pi anL} RI_0.$$

The great advantage of this method is that there is no need to screen anything. There is at any time only one oscillating circuit in action: either the local oscillator is on the amplifier or else the incoming signals. Screening involves inconvenient complications and means bulky apparatus, and no small cost. Perfect screening, specially in the neighbourhood of a powerful amplifier, is at best a very difficult matter. The best efforts may some time leave an uneasy doubt regarding its effectiveness. A further advantage is that the method is objective and does not depend upon the person carrying out the experiment.

A set exactly following the description given by Hollingworth was installed in the Radio Laboratory of the Indian Institute of Science, and worked very satisfactorily during observations being made every day on the strength of Madras Radio.

The foregoing paper is the substance of a lecture given by the auther to the Electrical Engineering Society of the Indian Inst. of Science in Dec. 1925, and submitted to the Editor in the following year.

The Demonstration of a New Precision Wavemeter Condenser.

By W. H. F. Griffiths, A.M.I.E.E., Mem.I.R.E.

At the Physical Society's recent exhibition of apparatus, the new Sullivan-Griffiths variable air condenser was demonstrated as a component of a sub-standard wavemeter. The instrument exhibited was the first model built on the lines indicated in the author's article in the February issue of this journal, and interesting results were obtained.

The principle, it will be remembered, is that of series complementary gaps in which the inverse law connecting capacity with gap distance is neutralised by the inverse law connecting reactance with capacity. It will also be remembered that a necessary feature of design is the screening of adjacent plate sections in order to eliminate all capacities to moving plates which, by remaining constant, tend to prevent the complementary changes in the capacities of adjacent gaps which form the arms of a number of Wheatstone bridges connected in parallel.

The condenser had, for the purpose of the demonstration, a fine screw thread bearing by which the entire moving system could be lowered relatively to the fixed system, thus providing a simple means by which the wearing of the bearing or other mechanical changes with age could be imitated.

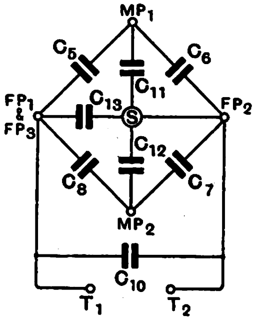


Fig. 1

An actual displacement amounting to 5 per cent. of the total dielectric gap distance was in this manner made while the heterodyne wavemeter, of which it formed part, was oscillating. The change of frequency produced by this displacement was indicated by the change of frequency of beating with the 20 kilocycle harmonic of a standard multivibrator wavemeter, the beats being recorded on a syphon recorder tape on which, for time marking, seconds were also being recorded by impulses from a pendulum. The initial beat frequency recorded was 5 per second, and this increased to 6 per second upon effecting the displacement—a frequency change of 1 part in 20,000. The demonstration was made with the condenser at its mid-scale (90 degrees) setting.

The change that occurred was chiefly due to the presence of constant capacities C_{11}, C_{12} of the paralleled Wheatstone bridge connected condenser plates of Fig. 1, owing to the fact that a metal central shaft had been employed. It can be shown that shaft capacities C_{11}, C_{12} of the order 1.0 $\mu\mu$F per plate will produce an inconstancy of this order by virtue of the fact that, being constant, they tend to prevent the complementary changes of reactance of the series gap capacities C_5, C_6 and C_7, C_8 upon which the whole principle of constancy depends.

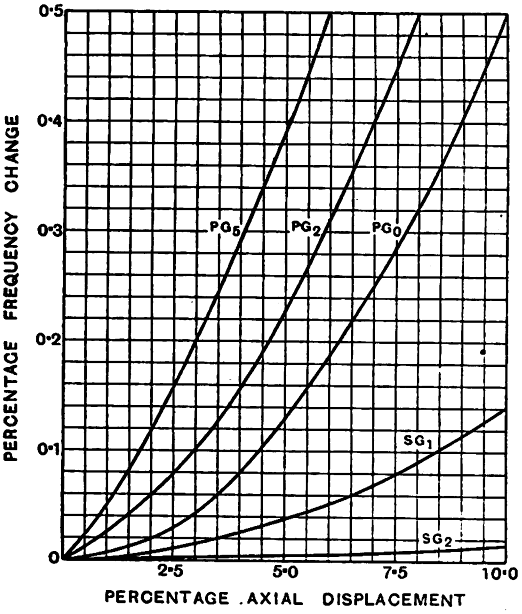


Fig. 2

The degree of inconstancy represented by this change of frequency is, of course, extremely small, especially when compared with that which would be obtained with a similar displacement on an ordinary condenser. Such a comparison is effected in Fig. 2 in which PG_0 PG_2 and PG_5 are calculated curves for an ordinary parallel gap condenser with correctly set plate systems, 2 per cent. initially displaced systems, and 5 per cent. initially displaced systems respectively. SG_1 is a calculated curve for a series complementary gap condenser without inter-section screening and SG_2 the curve plotted from actual results of the demonstration. Curve SG_1 will, of course, vary greatly with scale reading, the frequency change becoming much greater for lower scale settings.

The advantage of inter-section screening is, however, sufficiently marked by the comparison of the curves SG_1 and SG_2, and it is interesting to note that this screening may be effected in a very simple manner by displacing, relatively, through 180 degrees, alternate moving plates. The latter may then be completely screened from one another by suitably shaped fixed plates without the introduction of any special screening plates, such as those shown at A and A_1 in Figs. 15 and 16 of the February article.

A Bridge for the Measurement of Inductance and Capacity.

By Dr. G. Zickner.

TO the wireless amateur engaged on experimental work, the knowledge of the inductance and capacity of a circuit is of great importance, for the frequency and wavelength of an oscillatory circuit are primarily fixed by these two magnitudes. Although sufficiently exact measurements of capacity can be performed without difficulty with the aid of the convenient capacity bridge which is generally used, there has not hitherto been available a corresponding arrangement for the measurement of inductance. The measuring device described below is capable of measuring in a very short time any inductance whose value lies between ten and a hundred thousand microhenries (10^4 to 10^8 cm.) In addition, the apparatus has the advantage that it can be converted, by the turn of a switch, into a capacity bridge with which capacities from about $50\mu\mu$F. to about 1 μF. can be measured in the usual simple manner. The accuracy of measurement, whether for inductance or capacity, amounts to about one to a few units per cent. The commercial production of the apparatus has been undertaken by the firm of Dr. Georg Seibt, Berlin-Schöneberg; it can, however, be made at home without much difficulty by any reasonably skilled constructor.*

The apparatus is an application of the well-known Maxwell bridge-circuit. Two opposite arms of the bridge contain only resistances, the third contains a variable condenser in parallel with a resistance, while the fourth consists of the inductor with a resistance in series. (Fig. 1.) The variable condenser covers a capacity range from about 50 to about 1,100 $\mu\mu$F. The resistance in arm 1 has the value of 10,000 ohms; in arm 4 there are four resistances, of 10,000, 1,000, 100, and 10 ohms, which can be interchanged by means of a switch. The apparatus thus possesses four separate ranges making up the total range of 10^{-5} to 10^{-1} henry.

Regarded as an alternating current bridge, the fulfilment of two conditions is required. One is satisfied by adjustment of the variable condenser, the other by adjustment of the high resistance connected in parallel with it. Since a reliable and continuously variable resistance of high ohmic value is not available, a resistance variable in steps is employed, and coarse adjustment is made with this. Fine adjustment is then obtained by the small resistance in the inductance arm, which is furnished in addition with a special vernier adjustment. It is therefore necessary to adjust the variable condenser and the resistance in turn until complete silence is obtained in the telephones.

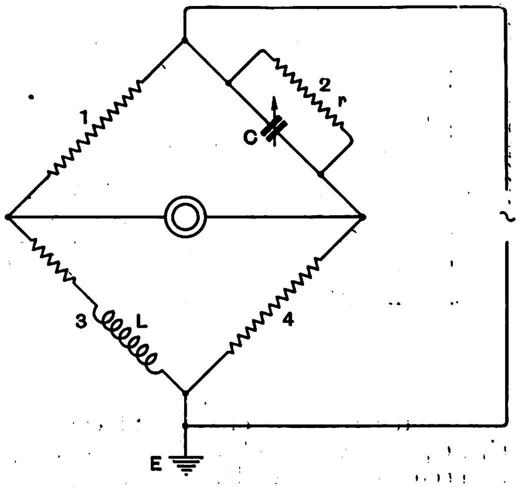


Fig. 1

It has been found, both by calculation and from practical experience, that it is necessary to attend to the following points :—

The resistance r in the capacity arm must be almost completely free from capacity, or it will falsify the reading of the condenser. The resistance in the inductance arm must be as free as possible from inductance, for otherwise its inductance l will be added to that of the coil and measured with it. It follows that a correction must sometimes be introduced in the measurement of small inductances. The time-constants θ_1 and θ_4 of the resistances in the remaining arms 1 and 4 of the bridge enter into the bridge-relations.*

---

* On this point *see* G. Zickner, "Eine technische Induktivitäts messbrücke," *Zeitschrift für Fernmeldetechnik*, Vol. 8, p. 59, 1927.

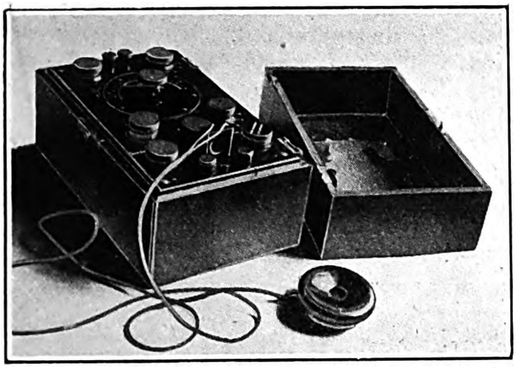


Fig. 2

The fundamental equation of the bridge reads:

$$L + l = r_1 r_4 \left(C + \frac{\theta_1 + \theta_4}{r} \right).$$

It is therefore necessary, by employing a special mode of winding, to keep the time-constants of these resistances sufficiently small to ensure that the correction $\frac{\theta_1 + \theta_4}{r}$ shall be negligible in comparison with C; further assistance in this direction can also be had by choosing the largest possible value for r. By so doing a small value for the correction l is simultaneously achieved.

The apparatus is worked by a buzzer, which is connected through a transformer. The lay-out is so chosen that any possible stray field that may be present due to the transformer affects but little the leads to the bridge. Fig. 2 gives an illustration of the apparatus.

Since the capacity curve of the condenser is practically a straight line, the calibration curves of the bridge are also straight lines.

By the movement of a reversing switch the two arms 3 and 4 can be interchanged, thereby converting the apparatus into an ordinary capacity bridge of the type shown in Fig. 3. The terminals to which, in the previous application of the bridge, the inductor under examination was connected, are now joined to the condenser which is to be measured.

These considerations lead to the following procedure for the measurement of inductance:—

After connecting the inductor to be measured and the telephones, and earthing the terminal provided for that purpose, the main switch is set for inductance measurement and the buzzer is set going. Then, first with the range-switch and condenser, and possibly also with the switch controlling the high resistance, the range within which the silent point lies is determined. The point of complete silence in the telephones is then sought by alternate adjustment of the condenser and of the coarse or fine adjustment of the resistance in the arm containing the inductance, and at the same time the stepped resistance is brought, in the interests of accuracy, to as high a value as possible. The value of the inductance is very simply determined

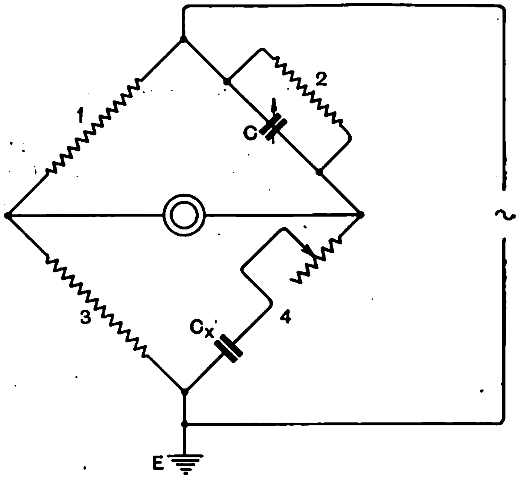


Fig. 3

---

* If l is the inductance and c the self-capacity of a resistance r, then the expression $\theta = \frac{l}{r} - cr$ is called the time-constant of the resistance.

from the setting of the condenser and the calibration curves provided. For coils of low inductance the correction *l*, mentioned above, must be introduced; its value is read off from an extra correction-curve.

Mutual inductance can also be determined by the apparatus. For this purpose primary and secondary coils are connected in series in the same sense, and the self-inductance of the two together is measured. Let this value be L_a. The connections to one of the coils are then reversed, and the measurement is repeated, obtaining the value L_b. Then the mutual inductance M between the two coils is given by $M = \frac{L_a - L_b}{4}$.

For measurements of capacity the main switch is set for this purpose. Coarse and fine-adjusting resistances in the testing-arm are then short-circuited. The stepped resistance is set to infinity. Then the measurement is performed in the usual way by adjustment of the variable condenser alone. It is only in the measurement of very large condensers, with high losses, that, to a limited extent, the resistances in arms 2 and 4 need be brought into use to improve the sound-minimum.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain

The Performance of Valves in Parallel.

To the Editor, E.W. & W.E.

SIR,—Col. Edgeworth's courteous explanation of the reasons which prompted him to challenge my treatment of "The Performance of Valves in Parallel" makes it desirable for me to add a final word in apology for a title which was perhaps rather too general for the text which followed.

R. P. G. DENMAN.

Science Museum, S.W.7.

Good Quality in H.F. Amplifiers.

To the Editor, E.W. & W.E.

SIR,—Mr. C. C. Inglis' article in your March issue "Good Quality in H.F. Amplifiers" appears to be entirely based on the tacit assumption that with a tuned anode coupling the voltage passed on to the grid of the next valve is proportional simply to the impedance of the tuned circuit to an externally applied E.M.F.

But surely this is not correct except in the extreme case where the impedance of the part of the circuit external to the tuned circuit is itself very large compared with that of the tuned circuit?

In the case of a tuned anode coupling the A.C. anode resistance of the valve constitutes this external circuit and is to be regarded as the seat of the alternating E.M.F. to which the potential difference developed across the tuned circuit is due. This tuned circuit, consisting of an inductance with resistance, in parallel with a capacity, is in series with the resistance of the valve, and the proportion of the total E.M.F. due to the valve which is impressed on the grid of the next valve is given in all circumstances by the vector expression

$$\frac{Z}{\rho + Z} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where Z denotes the impedance of the tuned circuit and ρ the A.C. anode resistance of the valve.

When the circuit is tuned for maximum potential difference across the tuned circuit, this P.D. is in phase with the E.M.F. and the impedance Z is equal to $\frac{L}{RC}$, where R is the actual resistance of the tuned circuit, so that the above expression reduces to the scalar one

$$\frac{\frac{L}{RC}}{\rho + \frac{L}{RC}} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

In determining the fraction of the total E.M.F. which is passed on to the next valve at a non-resonant frequency, (1) should strictly be evaluated as a vector expression, but so long as the impedance of the tuned circuit still has a value comparable with that at the resonant frequency, no great error is introduced by treating (1) as a scalar function. In any case the result of calculating the P.D. at the non-resonant frequency on this basis will be to give a value *lower* than would be obtained by the more accurate calculation.

Making the calculation on this approximate basis for the example given by Mr. Inglis of a tuned circuit of 183μH inductance, 0.0002μF capacity and 5 ohms resistance, with a valve resistance of 20,000 ohms, $\frac{L}{RC} = 183{,}000$, so that the value of (1) at the resonant frequency is

$$\frac{183{,}000}{20{,}000 + 183{,}000} = 0.902$$

while at the non-resonant frequency which reduces the impedance of the tuned circuit by 5 per cent. (1) becomes (or is strictly slightly greater than)

$$\frac{173{,}850}{20{,}000 + 173{,}850} = 0.897$$

i.e., a reduction of only 0.005, or rather more than one-half of 1 per cent. of the first value.

In calculating the band of frequencies corresponding to a 5 per cent. reduction of the impedance of the tuned circuit, the actual resistance of the tuned circuit must be used as in the first of Mr. Inglis' examples, so that the band of frequencies covered is 1,500 cycles—with a reduction, however, of the P.D. of about half of 1 per cent.

A reduction of 5 per cent. of this P.D. would require a reduction of the impedance of the tuned circuit by 34.6 per cent., *i.e.*, $n = \dfrac{1}{0.654} = 1.53$, giving a band of frequencies of 5,030 cycles. Mr. Inglis' value for this case is 15,000 cycles.

In the case of his third example, using a value of 100,000 ohms, a reduction of 12¾ per cent. of the tuned circuit impedance gives a 5 per cent. reduction of the P.D.

In this case $n = \dfrac{1}{0.8725} = 1.145$, and the band of frequencies covered is only 2,430. Thus in both examples the band of frequencies covered is very much less than obtained by Mr. Inglis' method.

This, of course, merely emphasises his point of view, if one agrees with his opinion that the P.D. must not be allowed to fall by more than 5 per cent. over the band of frequencies it is required to use, but most people will probably agree with the Editor's remark that this limitation is much too stringent.

Where only one stage of H.F. amplification is used one would think that a reduction of the P.D. by at least 20 per cent. should be permissible without the ear being able to detect any appreciable difference in quality.

This value leads to values of n in the two examples of 1.706 and 3.53, giving frequency bands of 14,700 and 6,000 cycles respectively. For a band of 12,000 cycles the maximum permissible valve resistance is about 26,000 ohms, or only half the value which Mr. Inglis finds for a 5 per cent. reduction of the tuned circuit impedance.

E. A. Biedermann.

Brighton.

To the Editor, E.W. & W.E.

Sir,—I read with interest the article on "Good Quality in H.F. Amplifiers" by Mr. C. C. Inglis in the March issue of *E.W. & W.E.* In my opinion the author is not quite correct in calculating the impedance of the plate circuit for different frequencies, and considering the valve as a parallel resistance, for really the valve acts as a series resistance with respect to the E.M.F. Considered from the point of view of selectivity he should have determined the voltage at the terminals of the impedance in the plate circuit.

This voltage is:

$$v_1 = \mu v_g \frac{Z}{R_i + Z} \quad \cdots \quad \cdots (1)$$

where: μ = amplification constant.
v_g = grid voltage.
R_i = valve resistance.

Now considering the resulting impedance, with R_i parallel to Z, we find:

$$Z_t = \frac{ZR_i}{R_i + Z} = R_i \frac{Z}{R_i + Z} \quad \cdots (2)$$

Both formulæ (1) and (2) give the same curve but on different scales if v_1 or Z_t is plotted against frequency for constant R_i, and for this reason the expression

$$\omega_A - \omega_B = \frac{R}{L}\sqrt{n^2 - 1}$$

derived by the author is correct.*

If, however, the influence of a *variable* R_i had been studied, the result would have been quite wrong: Formula (1) shows that for small values of Z, R_i has a large influence, whereas in form (2) exactly the reverse is the case. The exact method is therefore to consider the *voltage* variations, and not the *impedance* variations.

Moreover, I derived the expression of $\omega_A - \omega_B$ in the following way and arrived at somewhat deviating results.

The voltage drop in Z is proportional to $\dfrac{Z}{Z + R_i}$.

Z is composed of an inductance L and resistance r, shunted by a capacity C. Thus:

$$Z = \frac{(j\omega L + r)\dfrac{1}{j\omega C}}{j\omega L + \dfrac{1}{j\omega C} + r}.$$

Now r can always be neglected with respect to ωL, and in that case:

$$Z = \frac{L/C}{r + j\left(\omega L - \dfrac{1}{\omega C}\right)}$$

and

$$\frac{Z}{R_i + Z} = \frac{\dfrac{L/C}{r + j\left(\omega L - \dfrac{1}{\omega C}\right)}}{R_i + \dfrac{L/C}{r + j\left(\omega L - \dfrac{1}{\omega C}\right)}}$$

$$= \frac{L/C_r}{\dfrac{L}{C_r} + R_i + j\dfrac{R_i}{r}\left(\omega L - \dfrac{1}{\omega C}\right)}$$

$$= \frac{L/C_r}{\sqrt{\left(\dfrac{L}{C_r} + R_i\right)^2 + \dfrac{R_i^2}{r^2}\left(\omega L - \dfrac{1}{\omega C}\right)^2}} \cdots \quad \cdots (3)$$

In the resonance case:

$$\frac{Z_r}{R_i + Z_r} = \frac{L/C_r}{\dfrac{L}{C_r} + R_i} \quad \cdots \quad \cdots (4)$$

Putting $\dfrac{(4)}{(3)} = n$, we find easily:

$$\left(\omega L - \frac{1}{\omega C}\right)^2 = \left(r + \frac{L}{CR_i}\right)^2 (n^2 - 1)$$

$$\omega L - \frac{1}{\omega C} = \pm\left(r + \frac{L}{CR_i}\right)\sqrt{n^2 - 1} = \pm A.$$

---

* For this statement I am indebted to Mr. Posthumus.

From this we find :

$$\text{I. } \omega = \frac{A}{2L} \pm \sqrt{\frac{A^2}{4L^2} + \frac{1}{LC}}.$$

$$\text{II. } \omega = -\frac{A}{2L} \pm \sqrt{\frac{A_2}{4L^2} + \frac{1}{LC}}.$$

The only roots which give positive values of ω are

$$\omega_A = \frac{A}{2L} + \sqrt{\frac{A^2}{4L^2} + \frac{1}{LC}},$$

$$\omega_B = -\frac{A}{2L} + \sqrt{\frac{A^4}{4L^2} + \frac{1}{LC}}.$$

Hence :

$$\omega_A - \omega_B = \frac{A}{L} = \frac{r + \frac{L}{CR_i}}{L} \sqrt{n^2 - 1}$$

which is the same expression as found by Mr. Inglis. For $\frac{L}{CR_i}$ is nothing but the (parallel) valve resistance reduced into a series resistance.

We see, however, that it is not necessary to assume the resonance curve to be symmetrical, and that the expression applies for any value of n and not only for small ones. The only approximation made is that r is small compared with ωL. The formula appears to be much more general than the author assumes.

Of course a 5 per cent. decrease is, as you remarked in an Editorial footnote, far too stringent. A better method is to calculate n for a given value of the valve resistance, of, say, 100,000 ohms and see what is the result. Assuming the same values as the author for L and C, but a coil resistance of 20 ohms, which in practice is more probable than 5 ohms, we find $\omega_A - \omega_B = 2\pi \times 20{,}000$, that is a band width of 10,000 cycles on each side of the resonant frequency, $n = 1{\cdot}27$, which, of course, is still quite permissible. So there need not be any fear of distortion by the introduction of a valve of the screened grid type in the H.F. amplifier.

A. VAN SLUITERS.

Eindhoven, Holland.

The Radiation Resistance, etc., of Half-wave Aerials.

To the Editor, E.W. & W.E.

SIR,—The February issue contains an article by Mr. E. Green on the radiation resistance of half-wave aerials.

It is there stated that this quantity comes out to be 80 ohms, which the author proves by calculating the average current along the antenna and so on.

Now we have in the formula of Mr. van der Pol, jun. (*Jahrbuch der D.T.* xiii, 1918, p. 229) a more accurate tool for calculation. The formula referred to is rather complicated, but in the special case under consideration $\left(h = \frac{\lambda}{2}\right)$ it can be shown that

$$R_s = 46.77 + 45 . \log_e \pi + 15 . Ci\, 4\pi - 60 . Ci\, 2\pi \text{ ohms,}$$

which gives a value in the close proximity of 100 ohms. The function Ci is the integral-cosine

$$\left(Ci\, a = -\int_a^\infty \frac{\cos x}{x} . dx \right)$$

The formula of van der Pol is only correct when we can assume a perfectly conducting earth, and cannot consequently be used on very short wave-lengths.

Nevertheless, by taking into account the real emission in the Hertzian case, a radiation resistance of 100 ohms may be expected, differing from the value of 80 ohms found by Mr. Green, who only considers the geometrical distribution of current in the well-known Lipol formula, but not the true phase-values of the contributions from different parts of the antenna.

E. T. GLAS.

Kungsbacka, Sweden.

Resistance-capacity Amplification with Screened Valves.

To the Editor, E.W. & W.E.

SIR,—In the February number of your journal *E.W. & W.E.*, there is an article entitled, "A New Method of Using Resistance-Capacity Amplification with Screened Grid Valves," by John J. Dowling. I take the liberty of drawing your attention to the fact that the matters dealt with in this article are given in my book, "Der Bau von Widerstandsverstärkern" (The Construction of Resistance Amplifiers). In the first edition of my book, published in the winter of 1925, I dealt shortly with the subject on pp. 47 and 48. In the second edition, which appeared in March, 1926, the same question is touched upon on pp. 70 and 71. It is there stated: "It is advisable not to raise the screen-grid voltage appreciably above some 30 volts, for otherwise it is possible for the actual voltage on the anode to be considerably lower than the voltage on the screening grid, in the middle of the working range, on account of the voltage-drop in the external resistance. For one thing this influences unfavourably the current-distribution in the valve, and it also encourages the production of secondary electrons, which certainly may increase the amplification, but are a source of distortion through rendering the amplification unsymmetrical."

Since at that time there were not available any screened-grid valves really suitable for the purpose, I did not go into the matter more thoroughly. In common with Mr. Dowling I regarded the amplifier, on account of the danger of distortion by this method, as particularly suitable for telegraphy. More recently I have nevertheless pursued this problem further, and it appears that very stable operation can be obtained with the high anode resistances that I have employed. With the Telefunken screened-grid valve I have for example obtained by this method a voltage-amplification of 400 times. Highly promising results have been obtained by applying this method to an aperiodic high-frequency amplifier, although there remain under the conditions existing at present certain difficulties in connection with self-oscillation.

Berlin. MANFRED VON ARDENNE.

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

On Round-the-World Signals.—E. O. Hulbert. (*Proc. Inst. Radio Engineers*, 16, pp. 287-289, March, 1928.)

A note raising the question whether, for the round-the-world ray, a path following the curvature of the earth, as tacitly assumed by Quäck and Howe, is not the real path taken by the radio signal. The writer shows that the ray might quite well go round the earth in a sort of polygon when, incidentally, small movements of the Kennelly-Heaviside layer would be expected to cause violent fading of the signal—as is observed.

The fact that the actual path taken by the ray depends upon the distribution of electrons in the upper atmosphere makes the question of particular interest.

Measurements of the Effective Heights of the Conducting Layer and the Disturbances of 19th August, 1927.—O. Dahl and L. Gebhardt. (*Proc. Inst. Radio Engineers*, 16, pp. 290-296, March, 1928.)

An account is given of further improvements in the echo method of observing effective heights of the reflecting layer. A table of values is given showing effective heights at various times of day from 15th to 25th August, 1927, covering a period of general disturbance in transmission phenomena. The table shows an increase of height after the disturbance as compared with the days preceding it. The data obtained are compared with those furnished by Mount Wilson on disturbances in sun spots as well as the general condition of radio reception. An unusually active spot was observed at Mount Wilson several days before 19th August. If it was responsible for the disturbance its effect must have been cumulative. More systematic data are necessary to ascertain whether the rise in heights observed is characteristic for radio disturbances covering large areas.

Une Recrudescence Importante des Taches Solaires dans la Deuxième Quinzaine de Février, 1928 (Significant renewed activity of sun spots in the last fortnight of February, 1928).—H. Memery. (*Comptes Rendus*, 186, pp. 629-631, 5th March, 1928.)

Correlation of Long Wave Transatlantic Radio Transmission with other Factors affected by Solar Activity.—C. N. Anderson. (*Proc. Inst. Radio Engineers*, 16, pp. 297-347, March, 1928.)

A detailed presentation of the results of a study of long wave transatlantic radio transmission in its relation to a number of phenomena commonly thought to be manifestations of solar activity, namely: the occurrence of sun spots, the variations of the sun's radiation, disturbances of the earth's magnetic field, atmospheric electricity, the aurora, and earth currents. The results of the correlation are set out at length and are best understood by referring to the numerous graphs that are reproduced and the tables given. A bibliography of the subject is appended.

Report of the Chairman of the Commission on Radio Wave Propagation, International Union of Scientific Radio Telegraphy.—L. W. Austin. (*Proc. Inst. Radio Engineers*, 16, pp. 348-358, March, 1928.)

The work of the Commission on Radio Wave Propagation covers such a wide field of investigation that it was thought best to confine this report to a discussion of the subjects on which the various workers are not yet entirely in accord, or those in which the conclusions are not yet definitely established. The report is followed by a list of some of the questions suggested by the experimental material.

The Attenuation of Wireless Waves over Land.—R. H. Barfield. (*Journ. Inst. Elect. Eng.*, 66, pp. 204-218, February, 1928.)

A paper read before the Wireless Section of the Institution, 7th December, 1927, together with the discussion that followed. An abstract of the paper appeared in *E.W. & W.E.* of January, pp. 25-30.

Discussion on Long Distance Radio Receiving Measurements at the Bureau of Standards in 1925 (L. W. Austin).—B. H. Kynaston. (*Proc. Inst. Radio Engineers*, 16, pp. 359-360, March, 1928.)

Sur la Vitesse de Propagation des Ondes Radiotélégraphiques (On the velocity of propagation of radio waves).—A. Lambert. (*Comptes Rendus*, 186, pp. 686-688, 12th March, 1928.)

It is pointed out that the values for the speed of propagation of radio waves deduced from other data all lead to figures systematically and perceptibly less than 300,000 km./sec., the general mean coming out to 247,000 km./sec. (± 9,000 km.).

Étude de la Couche d'Ozone de la Haute Atmosphère pendant la Nuit (Investigation of the layer of ozone in the upper atmosphere during the night).—D. Chalonge. (*Comptes Rendus*, 186, pp. 446-448, 13th February, 1928.)

It is known that the terrestrial atmosphere contains ozone which is practically localised in the upper regions at an altitude of 40 to 50 kilometres. Brought to atmospheric pressure, it would constitute a thin film of varying thickness, in the neighbourhood of 3 millimetres, all round the earth. The permanence of this layer of gas at high altitude, as well as certain of its fluctuations in thickness, can be explained by the opposite effects on the molecules of oxygen and ozone of two kinds of ultraviolet solar radiation: that creative and that destructive of ozone. The purpose of the present investigation is to find out whether the proportion of ozone changes when solar radiation ceases to act, that is whether it differs by night and by day. The method employed is outlined and the preliminary results are given. These indicate that while the thickness of the ozone layer remains constant during a same night, it is perceptibly greater by night than by day. It is stated that these first results require confirmation by a longer series of experiments.

TRANSMISSION.

STRAHLUNGSDICHTE UND EMPFANGSFLÄCHE (Radiation density and receiving Surface).—M. Dieckmann. (*Zeitschr. f. Hochfrequenz.*, 31, pp. 8–15, January, 1928.)

A contribution to the rating of radio stations. It is shown that in the usual formula for calculating receiving efficiency in relation to the constants of transmitting and receiving antennæ, as well as the current in the transmitting antenna, the factors entering in can be gathered into two groups, one of which gives the energy density at the place of reception and the other the magnitude of the Rüdenberg absorption or receiving surface. At the same time a means of rating transmitters—one that has been suggested previously—is derived from the energy density reduced to a distance of one kilometre from the transmitter.

The dependence of the size of the receiving surface, as well as the current received, upon the antenna constants, is discussed with the help of curves and photographs of models.

In order to consider the degree of efficiency of receiving stations, the notion of the receiving value of a station is developed as the quotient of outgoing energy and energy density at the place of reception.

The deductions at first drawn only for open antennæ are extended to frame antennæ.

The representation of the phenomena by means of radiation density and receiving surface is applied to secondary radiators and reflector arrangements.

COMPENSATION DES COURANTS INDUITS ENTRE ANTENNES EMETTRICES VOISINES (Compensating the currents induced between neighbouring transmitting antennæ).—H. Chireix and R. Villem. (*Revue Generale de l'Electricité*, 23, pp. 523–536, 24th March, 1928.)

The phenomena connected with mutual induction between neighbouring antennæ are analysed qualitatively together with their reciprocal electrostatic action. Two methods of diplex transmission are then indicated, one by electromagnetic coupling between the antennæ by means of either a mutual inductance or a self-inductance common to the two antenna circuits, the other by using a self-inductance forming an anti-resonant circuit with the capacity between the antennæ. The authors give the precise signification of this capacity, and the method for calculating it, as well as the expressions for the self-inductances and mutual inductances of the antennæ, and conclude with some practical results.

I.E.E. WIRELESS SECTION: CHAIRMAN'S ADDRESS.—A. G. Lee. (*Journ. Inst. Elect. Eng.*, 66, pp. 12–24.)

Address delivered before the Wireless Section, 2nd November, 1927, considering chiefly the problem of atmospherics and transatlantic telephony.

RECEPTION.

UNTERSUCHUNGEN AN EINEN EMPFANGSGERÄT FUR KURZE WELLEN (Investigation of a receiving instrument for short waves).—O. Cords. (*Zeitschr. f. Hochfrequenz.*, 31, pp. 1–7 and 39–43, January and February, 1928.)

Abridgment of a Jena dissertation dealing in detail with the generation, reception and measurement of waves 3–6 metres in length.

WORKING ON 8 METRES.—C. D. Abbott. (*Wireless World*, 22, pp. 135–138, 8th February, 1928.)

Description of a receiver and transmitter for ultra-short waves.

ON THE DISTORTIONLESS RECEPTION OF A MODULATED WAVE AND ITS RELATION TO SELECTIVITY.—F. Vreeland. (*Proc. Inst. Radio Engineers*, 16, pp. 255–280, March, 1928.)

The paper is summarised as follows:

The importance of overtones in the faithful reproduction of speech and music. Overtones are transmitted by the extreme side bands of a modulated wave. Distortionless reception of the full side bands necessary for faithful reproduction. Crowding of the air channels brings adjacent waves into such close juxtaposition that selectivity demands a sharp cut-off at the limits of the band. Selectivity by the usual resonance methods trims the side bands. Attempts at compromise by employing damped resonant circuits do not achieve distortionless reception and sacrifice selectivity. Description of an amplifier giving uniform amplification over the entire band width with a sharp cut-off. Description of a band selector having an approximately rectangular frequency characteristic. Frequency control and volume control. Various applications of the band amplifier and the band selector to broadcast reception.

ON THE THEORY OF POWER AMPLIFICATION.—M. von Ardenne. (*Proc. Inst. Radio Engineers*, 16, pp. 193–207, February, 1928.)

An English rendering of the paper "Zur Theorie der Endverstärkung" that appeared in the Zeitschrift für Hochfrequenztechnik of last October, pp. 116–123.

DIRECT COUPLED DETECTOR AND AMPLIFIERS WITH AUTOMATIC GRID BIAS.—E. H. Loftus and S. Y. White. (*Proc. Inst. Radio Engineers*, 16, pp. 281–286, March, 1928.)

Description of a system for the direct coupling of valves to give composite detection and amplification. The system is designed to avoid frequency discrimination in amplifying audio frequency, and to be free from electrical and acoustical feed-back effects. High-μ valves are used to control the output of the power amplifier through the aid of the very high filament-to-plate impedance of such valves with extremely small expenditure of energy therein, and in such a way as to avoid effect of so-called "detector overloading." Microphonic effects are avoided. A unique method of automatically regulating the system to be responsive to carrier currents of different intensities is described, and includes an extension of the automatic effect to volume control. The entire system is designed to be inexpensive and extremely simple in the matter of construction.

CALCULATIONS FOR RESISTANCE AMPLIFIERS.—A. L. M. Sowerby. (*E.W. & W.E.*, 5, pp. 201-203, April, 1928.)

HIGH-NOTE LOSS IN RESISTANCE AMPLIFIERS.—A. L. Sowerby. (*Wireless World*, 22, pp. 213-251 and 285, February and March, 1928.)

A paper in three parts dealing respectively with the important effect of incidental capacities, the measurement of working impedances and capacities, and practical applications to amplifier design.

ANODE AND GRID RECTIFICATION.—A. L. Sowerby. (*Wireless World*, 22, pp. 309-312, 21st March, 1928.)

A survey based on practical measurement, showing that each type of detector has its particular sphere of usefulness.

THE INDIRECTLY HEATED CATHODE RECEIVER.—A. P. Castellain. (*Wireless World*, 22, p. 238 and 7th and 21st March, 1928.)

SMOOTH REACTION CONTROL.—A. P. Castellain. (*Wireless World*, 22, pp. 361-364, 4th April, 1928.)

Discussion of the problem of the design of receivers without high-frequency amplification.

VOLUME CONTROL.—(*Wireless World*, 22, p. 360 4th April, 1928.)

Brief description of methods for reducing signal intensity.

PROGRESS IN RADIO RECEIVING DURING 1927.—A. N. Goldsmith. (*General Electric Review*, 31, pp. 64-69, January, 1928.)

ÜBER DEN SCHWINGKRISTALL (On the oscillating crystal).—K. Sixtus. (*Zeitschr. f. Techn. Physik*, 9, pp. 70-74.)

The static characteristic of a zincite-steel combination is investigated under various conditions. Since the deductions from a formula that takes account only of thermic effects are in agreement with the experimental results, it is concluded that the cause of the falling characteristic in the oscillating crystal is to be found in heat processes at the point of contact. The oscillograms obtained from the oscillations show that the periodic paths of current and tension are the same for both oscillating crystal and arc.

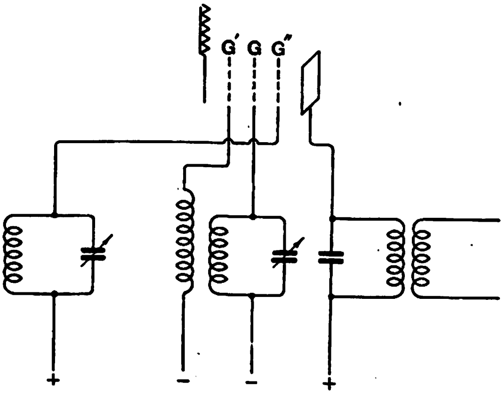
VALVES AND THERMIONICS.

THE APPROXIMATE THEORY OF THE SCREEN-GRID VALVE.—B. C. Brain. (*E.W. & W.E.*, 5, pp. 179-183, April, 1928.)

A paper showing how the general shape of the characteristic curves and the static constants, viz., amplification factor, differential anode resistance, mutual conductance, and interelectrode capacity can be predicted from consideration of the structural constants in the special type of four-electrode valve called the screen-grid valve.

LES LAMPES À TROIS GRILLES ET LEURS MONTAGES (Valves with three grids and their circuits).—M. Chauvierre. (*Radio-Revue*, 7, pp. 561-572, March, 1928.)

Valves with three grids have been known for some time, at least abroad, one type having been constructed by the firm of Siemens in Germany and another put on the market by the firm of Vatea in Czecho-Slovakia. It is stated that in the classic functions of detector and amplifier, the three-grid valve may be regarded as the perfection of the two-grid valve. It is not with the valve in these rôles, however, that this paper deals, but as a frequency changer. The author tried out several frequency-changing circuit-arrangements: the one he found the most interesting is reproduced below:



Experiments with this circuit are described, and its many advantages, which include great purity, suppleness and sensitivity.

FREQUENCY VARIATIONS OF THE TRIODE OSCILLATOR.—K. E. Edgeworth. (*Phil. Mag.*, 5, pp. 783-784, April, 1928.)

A note on Mr. D. F. Martin's paper in *Phil. Mag.* for November, 1927.

CHARACTERISTIC CURVES OF THE FOUR-ELECTRODE VALVE.—N. R. Hall. (*E.W. & W.E.*, 5, pp. 198-200, April, 1928.)

THE FRENOTRON VALVE—A VIENNA NOVELTY.—(*E.W. & W.E.*, 5, p. 214, April, 1928.)

ARE THERE TOO MANY TYPES OF VALVES?—E. V. Appleton. (*Wireless World*, 22, pp. 243-244, 7th March, 1928.)

VALVE CLASSIFICATION.—A. L. M.-S. (*Wireless World*, 22, pp. 321-322, 21st March, 1928.)

A suggested new scheme based on impedance and magnification factor.

THEORY OF THE INTERNAL ACTION OF THERMIONIC SYSTEMS AT MODERATELY HIGH FREQUENCIES.—Part I.—W. E. Benham. (*Phil. Mag.*, 5, pp. 641-662, March, 1928.)

Equations are given applying to a parallel plane thermionic system subject to potentials varying in time. These equations are similar to Child's equations for steady potentials, but contain extra terms. A solution of the alternating case is obtained, taking into account space-charge but neglecting emission velocities, in the special case of a small oscillatory potential superimposed on a large steady potential. The time of transit of the electrons appears in the solution. The theory is used to explain certain experimental results on the frequency variation of rectified current.

The qualitative agreement between theory and experiment is satisfactory, but the observed effect is much the greater. The discrepancies between theory and experiment are discussed at some length. It is pointed out that electrons emitted with certain velocities are liable to execute a to-and-fro motion about the surface of minimum potential. This effect would increase with the frequency, with a corresponding modification of rectified current.

ON ELECTRICAL FIELDS NEAR METALLIC SURFACES.—J. Becker and D. Mueller. (*Physical Review*, 31, pp. 431-440, March, 1928.)

An abstract of this paper was given in the *Review* for February (these abstracts, April, 1928, p. 225).

DIRECTIONAL WIRELESS.

SUR UN PROCÉDÉ DE VISÉE RADIOÉLECTRIQUE APPLICABLE À LA GÉODÉSIE (On a method of radio direction-finding applicable to geodesy).—P. Schwartz. (*Comptes Rendus*, 186, p. 73, 9th January, 1928.)

This is stated to be a first application of the radiogoniometer to precision measurement. Employing a receiver that was very sensitive, though without a divided circle, the author "sighted radioelectrically" stations both near and distant, and by progressively diminishing the heating of the valves, was able to determine exactly the azimuth of a station. It is estimated that the precision obtained compares with that of optical sighting. Two methods of observation are recommended: "sighting" the transmitting station directly by bringing the sound heard to an audible minimum and determining the "sights" of the audible limits of the station to the right and to the left, listening to a sound of medium intensity. A radiogoniometer, specially constructed for this purpose, would permit the application of the method of series to "sightings" and the obtaining of results comparable to those reached in the actual establishment of geodesic chains.

SUR UN NOUVEAU DISPOSITIF D'ALIGNEMENT PAR EMISSIONS HERTZIENNES (On a new method of course-setting by wireless).—J. Aicardi. (*Comptes Rendus*, 186, pp. 305-307, 30th January, 1928.)

Description of means to enable a ship or aeroplane to follow a given course in foggy weather. The device consists of two antennæ a small distance apart transmitting waves of the same length but with a well-defined phase difference. When the two waves are continuous and emitted with the same energy, we know that nodal lines are formed along which the field and consequently reception are zero. In the present system one antenna emits continuous waves, while the other waves modulated at a musical frequency. Owing to this difference between the two emissions, it is no longer necessary for the fields produced by the two antennæ to be equal for the nodal lines of the interference field to be clearly defined, places of silence occurring whenever the difference in phase of the two emissions reaches a certain value. It is explained why the precision of the arrangement is greater than that of the ordinary interference device, being capable of giving a result correct to one degree.

ROTATING-LOOP RADIO TRANSMITTERS, AND THEIR APPLICATION TO DIRECTION-FINDING AND NAVIGATION.—T. H. Gill and N. F. Hecht. (*Journ. Inst. Elect. Eng.*, 66, pp. 241-255, March, 1928.)

A paper read before the Wireless Section of the Institution, 4th January, 1928, an abstract of which was published in *E.W. & W.E.* for February, pp. 85-88.

SOME EXPERIMENTS ON THE APPLICATION OF THE ROTATING-BEACON TRANSMITTER TO MARINE NAVIGATION.—R. L. Smith-Rose and S. R. Chapman. (*Journ. Inst. Elect. Eng.*, 66, pp. 256-269, March, 1928.)

A paper read before the Wireless Section of the Institution, 4th January, 1928, an abstract of which was published in *E.W. & W.E.* for February, pp. 88-90.

A THEORETICAL DISCUSSION OF VARIOUS POSSIBLE AERIAL ARRANGEMENTS FOR ROTATING-BEACON TRANSMITTERS.—R. L. Smith-Rose. (*Journ. Inst. Elect. Eng.*, 66, pp. 270-279, March, 1928.)

A paper read before the Wireless Section of the Institution, 4th January, 1928, followed by the discussion on it and the two preceding papers. An abstract of the paper appeared in *E.W. & W.E.* for February, 1928, pp. 90-92.

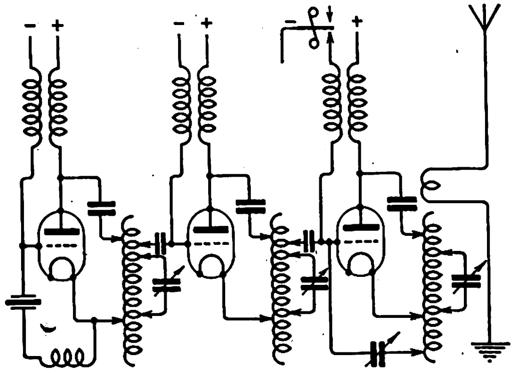
RADIO COMMUNICATION DEVELOPMENT IN AMERICA.—(*Electrical Review*, 102, p. 468, 16th March, 1928.)

The engineers of the Radio Corporation of America have developed a reliable method of high-frequency directive transmission, known as the R.C.A. Projector System, which is now in operation on several circuits. This system is stated to compare most favourably with the performance of the Marconi beam system in efficiency, and to offer some advantages in simplicity of construction and adjustment. The development of the system is the patent of the R.C.A., and other companies using it will have to do so on some arrangement with regard to royalties.

MEASUREMENTS AND STANDARDS.

Stabilisateurs de Fréquence Piézo-Électriques pour Emetteurs d'Ondes Courtes (Piezo-electric frequency-stabilisers for short-wave transmitters).—J. Jammet. (*L'Onde Electrique*, 7, pp. 5 and 63, January and February, 1928.)

After an elementary account of piezo-electric phenomena, and a rapid survey of some of their applications, the author gives a detailed account of the means he has employed to achieve stabilisation of frequency in short-wave transmitters. The circuit-arrangement developed, comprising pilot oscillator, frequency multiplier, and power valve, is shown below.



Piezoelektrische Kristalle als Frequenznormale (Piezo-electric crystals as frequency standards).—E. Giebe and A. Scheibe. (*Elekt. Nachr. Technik*, 5, pp. 65-82, February, 1928.)

In all piezo-electric resonators and oscillators, up to now, longitudinal oscillations have been exclusively employed. The present paper shows how transverse (flexural) and torsional oscillations can also be excited piezo-electrically, and throws light on the piezo-electric phenomena linked up with the elastic oscillations of quartz plates and on the laws of the natural high-frequency oscillations. Transverse and torsional oscillations should also be of value for practical measurements for the reason, among others, that their employment would considerably extend the range of frequency in which piezo-electric resonators can find application as frequency standards.

Der piezoelektrische Resonator in Hochfrequenzschwingungskreisen (The piezo-electric resonator in high-frequency oscillatory circuits).—Y. Watanabe. (*Elekt. Nachr. Technik*, 5, pp. 45-64, February, 1928.)

In a previous paper (*J.I.E.E.* of Japan, May, 1927) the author dealt with some new methods of measuring motional admittance and investigated the characteristics of the resonator for various special cases. In the present paper he considers the oscillation conductivity of the piezo-electric resonator, the properties of the crystal coupling, the piezo-electric oscillation generator and the crystal frequency stabiliser.

Some Practical Applications of Quartz Resonators.—(*E.W. & W.E.*, 5, pp. 215-219, April, 1928.)

Abstract of a paper read by Messrs. G. W. Cobbold and A. E. Underdown, before the Wireless Section, I.E.E., 7th March, 1928.

A Short Survey of some Methods of Radio Signal Measurement.—K. Sreenivasan. (*E.W. & W.E.*, 5, pp. 205-210, April, 1928.)

Apparatus Standards of Telephonic Transmission, and the Technique of Testing Microphones and Receivers.—B. S. Cohen. (*Journ. Inst. Elect. Eng.*, 66, pp. 165-203, February, 1928.)

A paper read before the Institution, 17th November, 1927, together with the discussion that followed.

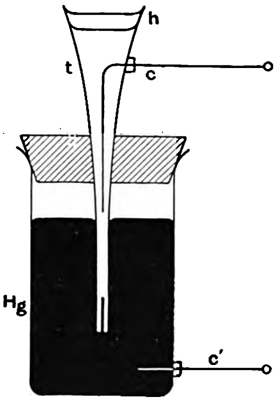
Mutual Inductance in Radio Circuits.—L. Hartshorn. (*E.W. & W.E.*, 5, pp. 184-188, April, 1928.)

SUBSIDIARY APPARATUS.

Microphone Electrocapillaire (Electro-capillary microphone).—M. Latour. (*Comptes Rendus*, 186, pp. 223-224, 23rd January, 1928.)

Description of a simple microphone, the principle of which is shown below.

The capillary tube *t*, whose cross section increases towards its upper opening, is filled with an electrolyte (salt or acidulated water) and dips into mercury. When talking at some distance from the apparatus, the speech is electrically reproduced in a receiver, inserted between the conductors *c* and *c′*. It is remarked that operation continues just the same when the circuit is broken by inserting a capacity, showing that it certainly is a question of an alternating electromotive force of capillary origin and not of the variation of a continuous current produced by the variation of a resistance.



Further, conversely, if an alternating tension of musical frequency is applied to the conductors *c* and *c′*, the instrument works as a telephone receiver.

Untersuchungen über Monotelephone (Research on mono-telephones).—R. Bauder and A. Ebinger. (*Zeitschr. f. Techn. Physik*, 9, pp. 65-69, February, 1928.)

Un Nouveau Haut-Parleur (A new loud-speaker).—(*Radio-Revue*, 7, p. 572, March, 1928.)

Brief description of a novelty loud-speaker called the "Phragmophone," which has the advantage of occupying very little space. Its principle in outline is that the air is set in motion by a stretched piece of cloth, caused to vibrate by two parallel wires carrying an iron disc, which is influenced by an excited electro-magnet.

Smoothing Condensers in Eliminators.—(*Wireless World*, 22, pp. 323–325, 21st March, 1928.)

Discussion of the effect of voltage rises due to inductive surges.

Gleichstrom-Hochspannungsmaschinen als Anodengeneratoren (High-voltage, direct-current machines for anode-potential supply in transmitters).—E. Rappel. (*E.T.Z.*, 48, pp. 1285–1290.)

Description of modern requirements in generators for transmitting stations, and up-to-date designs. The winding, connection, and commutation, and the cause and suppression of higher harmonics are discussed in detail. Data are given of a 3 kw., 3,000 volt, 1,500 r.p.m. motor-generator, built by a Swedish firm, which is in daily use at the Falun radio station. It is stated that no commutator ripple can be detected by headphones in the current from this generator.

Sur quelques Propriétés du Démultiplicateur (On some properties of the frequency sub-multiplier).—E. Rouelle. (*Comptes Rendus*, 186, pp. 224–226, 23rd January, 1928.)

Continuation of an investigation, the first results of which were given in Comptes Rendus, 185, p. 1450.

STATIONS : DESIGN AND OPERATION.

La Station Radiotéléphonique de Prague (The Prague broadcasting station).—E. M. Deloraine. (*L'Onde Electrique*, 7, pp. 21 and 45, January and February, 1928.)

A paper in two parts, the first of which is devoted to general considerations of the problem of broadcast transmission, the second to a description of the Prague installation. After describing successively the microphones and amplifiers, the broadcast transmitter, the alternators, multiple antenna and earth, the methods of measuring the antenna output are explained, and the degree of modulation for the different frequencies transmitted.

Der Deutschlandsender bei Königswusterhausen (The "Deutschland" transmitter near Königswusterhausen).—W. Meyer. (*Telefunken-Zeitung*, 9, pp. 69–89, January, 1928.)

A detailed account of this new high power broadcasting station constructed by the Telefunken Company for the German State to replace the station at Königswusterhausen of the same designation. Several illustrations are shown of the new station, which will have about six times the efficiency of the old one.

London's New Air Port.—W. G. W. Mitchell. (*Wireless World*, 22, pp. 130 and 170, 8th and 15th February, 1928.)

Illustrated description of the new direction-finding equipment installed at the Croydon Aerodrome for locating aircraft, and of the new transmitting aerials and plant for communicating with machines in flight erected at Mitcham Common, two miles away, in order to avoid obstruction to aircraft in landing and lessen interference with wireless reception.

220-Kv. Carrier-Telephony.—R. B. Ashbrook and R. E. Henry. (*Electrical World*, 91, pp. 495–497, 10th March, 1928.)

Description of the Southern California Edison Company installation embodying single-frequency duplex operation with selective ringing.

Short-Wave Transmissions.—(*Wireless World*, 22, pp. 150–152, 8th February, 1928.)

A list of stations throughout the world working below 100 metres, arranged alphabetically according to their call-signs.

The Design and Distribution of Wireless Broadcasting Stations for a National Service.—(*E.W. & W.E.*, 5, pp. 189–197, April, 1928.)

Abstract of a paper read by Capt. P. P. Eckersley, before the Wireless Section, I.E.E., 1st February, 1928.

GENERAL PHYSICAL ARTICLES.

The Wider Aspects of Cosmogony.—J. H. Jeans. (*Supp. to Nature*, 121, pp. 463–470, 24th March, 1928.)

The Trueman Wood Lecture delivered before the Royal Society of Arts, 7th March.

Referring to the cosmic radiation, the author states that, in a sense, this radiation is the most fundamental physical phenomenon of the whole universe, most regions of space containing more of it than of visible light or heat, and further, that there is no reason to doubt that it originates in the great nebulæ, and its amount is about what it ought to be, if it is evidence of the whole universe melting away into radiation (cf. Millikan, these Abstracts for March, p. 167).

Some Further Problems in Potential Difference.—G. W. O. Howe. (*E.W. & W.E.*, 5, pp. 175–178, April, 1928.)

Sur les Oscillations d'Ordre Supérieur d'un Circuit Oscillant (On the oscillations of an oscillating circuit of higher order).—M. Chenot. (*Comptes Rendus*, 186, pp. 743–745, 19th March, 1928.)

An examination of the conclusions drawn by Lord Rayleigh (Theory of Sound, 1, p. 200) as to the possible oscillations of a given mechanical system, by means of tests on an analogous use of electrical oscillations, relating to the question whether the different wavelengths possible correspond to a harmonic series.

High-Frequency Currents.—E. W. Marchant (*Journ. Inst. Elect. Eng.*, 65, pp. 977–988.)

The eighteenth Kelvin Lecture, delivered before the Institution, April, 1927.

Über Koppelschwingungen kontinuierlicher Teilsysteme (Coupled oscillations of continual partial systems).—E. Waetzmann and K. Schuster. (*Annalen der Physik*, 84, pp. 507–524.)

Sur les Equations du Champ Electromagnétique (On the equations for the electromagnetic field).—E. Brylinski. (*Revue Général de l'Electricité*, 23, pp. 167–168.)

Zur Theorie der Koppelschwingungenzwischen Telephonmembranen und Lufträumen (Theory of coupled oscillations between telephone membranes and air spaces).—K. Schuster. (*Annalen der Physik*, 84, pp. 525–552.)

MISCELLANEOUS.

La Télévision Electrique (Electric television). —A. Dauvillier. (*Revue Générale de l'Electricité*, 23, pp. 5, 61 and 117, January, 1928.)

In the first part of the paper the author outlines the history of television from 1875 to the present day, surveying critically the various systems that have been put forward. In the second part he describes his personal research resulting in the development of the "téléphote" and the "radiophote," where the principles of television are extended to the domain of X-rays.

Die neuesten Fortschritte des Bildtelegraphie - Systems - Telefunken - Karolus-Siemens (The latest developments in the Siemens-Karolus Telefunken system of picture telegraphy).—F. Schröter. (*Telefunken-Zeitung*, 9, pp. 5-10, January, 1928.)

Phototelegraphy.—(*Wireless World*, 22, pp. 356-359, 4th April, 1928.)

Details are given of an important new process for telegraphing newspaper illustrations.

Quelques Procédés d'Amplification des Courants Photo-Electriques et Applications à l'Emission des Bélinogrammes (Some methods of amplifying photo-electric currents with application to the transmission of "Belinogrammes").—M. P. Toulon. (*L'Onde Electrique*, 7, pp. 72-89, February, 1928.)

Paper read at a meeting of the S.A.T.S.F., December, 1927.

D. E. H.

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPRECOJ DE CIRKVITOJ.

Komuna Indukteco en Radio-cirkvitoj.—L. Hartshorn.

Unue konsiderita estas la ĝenerala ekzemplo de du bobenoj kun komuna indukteco kun la diversaj mem-kaj aliaj kapacitoj, kiuj ekzistas en praktiko. Per la ekvivalenta cirkvito montrita en ĉi-tiu ekzemplo, la aŭtoro traktas laŭvice pri komunaj induktecaj ekvacioj, aplikado al variometroj, efektivaj rezistecaj ekvacioj, mem-kapacitaj ekvacioj, la determino de la konsistantaj kapacitoj de transformatoroj, mem-induktecaj ekvacioj, k.t.p.

Kelkaj Praktikaj Aplikadoj de Kvarcaj Resonatoroj.

Resumo de prelego legita de S-roj. G. N. Gobbold, M.A., kaj A. E. Underdown ĉe la Senfadena Sekcio de la Institucio de Elektraj Inĝenieroj, Londono, je 7a Marto, 1928a.

Post enkonduka revuo pri fruaj aplikadoj de la kvarca kristalo, la aŭtoroj priskribas eksperimentan laboron faritan de ili ĉe la Eksperimenta Fako de Signaloj (Woolwich) de la Brita Armeo. La priskribo ampleksas la cirkvitojn uzitajn, la efekton de aera interspaco, cirkvitajn konstantojn, temperaturon, k.c.

Ili poste priskribas kelkajn instrumentojn desegnitajn por utiligi kristalajn oscilatorojn, laŭjene: (1) Kvarcaj Kristaloj kiel Aludaj Normoj kune kun Sub-norma Ondometro, (2) Kvarca kristalo en Ondometro donanta serion de Ondolongoj, kiuj estas ĉiuj Obloj de 100 metroj, (3) Kvarca Kristalo en instrumento donanta serion de frekvencoj, kiuj estas ĉiuj obloj de 1,000 Kilocikloj. La cirkvitoj estas ĉiuj ilustritaj, kaj raporto de la diskuto, kiu sekvis la legadon de la prelego, estas donita.

Kelkaj Pluaj Problemoj pri Potenciala Diferenco.

Redakcia artikolo, super la cefliteroj de Prof. Howe, pritraktanta kelkajn ekzemplojn de potenciala diferenco, kiuj eble povas esti miskomprenitaj. La unua ekzemplo estas tiu de magneta poluso enmetita en ringon metalan, kiam la ringo estas nefermita kaj fermita respektive. La rezonado estas poste aplikita al la kondiĉoj de ringo de izola materialo.

Kalkulado de Rezistecaj Amplifikatoroj.—A. L. M. Sowerby.

La ekzemplo pritraktita estas tiu de rezisteca kapacita ŝtupo funkcianta en grandpotencan valvon (LS5A).

La traktado sin koncernas pri la limoj de anodkurenta svingado, kradtensia svingado, krada potencialo, ŝtupa amplifado, k.t.p. Definitiva ekzemplo estas ellaborita por du malsamaj valvoj de konataj karakterizoj, montrante la metodon de elekto de la valvo por plenumi la bezonitajn kondiĉojn.

SENDADO.

La Desegnado kaj Distribuado de Senfadenaj Brodkastaj Stacioj por Nacia Servado.

Resumo de prelego legita de Kap. P. P. Eckersley, M.I.E.E., ĉe la Senfadena Sekcio de la Institucio de Elektraj Inĝenieroj, Londono, je la. Feburaro, 1928a.

Post enkonduka historia sekcio, la aŭtoro traktas pri la serva amplekso de brodkasta stacio kaj la diversaj detaloj pri desegno necesigitaj. Li poste diskutas aliajn ĝeneralajn problemojn de brodkasta distribuado, t.e., limigo de ondolongo, provizo de alternativaj programoj, kunigado de stacioj, unuobla ondolonga funkciado, kaj la proponita "regiona plano" por Britujo.

La dua parto de l'prelego estas dediĉita al la desegno de brodkastaj sendiloj. Post postulo pri la ĝeneralaj bezonoj por la sendiloj, la aŭtoro diskutas "altpotencajn" kaj "malaltpotencajn" modulajn sendilojn respektive, donante, sub la ĉi-lasta tipo, la kompletan cirkviton de la Daventry'a 5GB Stacio, kiu utiligas ĉi tiun sistemon.

Komparo inter la du sistemoj estas resumita, kaj la aŭtoro finas per kelkaj ciferoj pri la kosto de potenca provizado por brodkastaj stacioj.

Raporto pri la diskutado, kiu sekvis la legadon de la prelego, estas ankaŭ donita.

VALVOJ KAJ TERMIONIKO.

La Proksimuma Teorio de la Valvo kun Skrenita Kadro.—B. C. Brain.

La prelego traktas pri la ĝenerala formo de la karakterizaj kurvoj kaj statikaj konstantoj—amplifa faktoro, diferenciala anoda rezisteco, interelektroda kapacito, k.t.p.—de la valvo kun skrenita krado, kaj la antaŭdiro pri ĉi tiuj per strukturaj konstantoj.

Post ĝenerala enkonduka sekcio, interelektroda kapacito kaj voltkvanta faktoro estas pritraktitaj, la aŭtoro konkludante, ke la kapacito estas preskaŭ inverse proporcia je la distanco inter la skrenita krado kaj la kontrola krado. Sekundaria emisio estas poste konsiderita sub la rubrikoj, Ekzemplo I, tuta sekundaria emisio, kaj Ekzemplo II, la sekundaria emisio estas malpli ol saturiĝo. La ĝeneralaj konkludoj laŭ la antaŭa rezonado estas poste fine montritaj.

Karakterizaj Kurvoj de la Kvar-Elektroda Valvo.—N. R. Hall.

La prelego pritraktas la familion de karakterizaj kurvoj de la kvar-elektroda valvo sammaniere ĝenerale kiel pri la triodo, dividante la kurvojn en du grupojn, en unu el kiuj la interna, kaj en la alia la ekstera krado estas tenita je konstanta potencialo.

Kompleta serio de kurvoj estas donita por kolekto de valoroj de ĉiu el ĉi tiuj tensioj, kaj la konstantoj de la valvoj estas derivitaj.

Oni ankaŭ donas kurvojn de l'anoda tensio montrita kontraŭ internkrada tensio kaj eksterkrada tensio respektive, dum la alia krado estas konservita konstanta.

La "Freneton" Valvo.—Viena Novaĵo.

Mallonga artikolo super la ĉefliteroj de Prof. Howe priskribanta valvon elpensitan de D-ro. Pollak-Rudin de Vieno. La aranĝo konsistas el la apliko trans valvenmeta cirkvito de stabiligilo de ne-linia karakterizo. La elpensaĵo de D-ro. Pollak-Rudin enkorpigas ekstran anodon en la valvon, servitan per plilongigo de la filamento, tiel ke la valvo konsistas el triodo kaj diodo en la unu koverto, la diodo funkciante kiel la stabiliga elpensaĵo aludita.

MEZUROJ KAJ NORMOJ.

Mallonga Priskribo de Kelkaj Metodoj de Radio-signala Mezurado.—K. Sreeniasan.

En Sekcio A de l'artikolo, la aŭtoro unue donas ĝeneralan diskutadon pri la problemo, kun la nomoj de tiuj asociitaj kun kaj la teoria kaj la eksperimenta flankoj. Li poste diskutas plifruajn kaj malplifruajn eksperimentojn, kondukante ĝis la plimodernaj anstataŭigaj metodoj.

En Sekcio B, li pasas al revuo pri la diversaj metodoj. En la nuna numero la metodoj pritraktitaj estas (1) la metodo Vallauris, 1919a, farante observadojn en Italujo koncerne la sendadoj el Annapolis, (2) la aranĝoj uzitaj de Leŭt. Guierre de la Franca Militmaristaro sur la "Aldebaran" en 1919–20a, (3) la metodoj kaj cirkvitoj de Englund, Bown kaj Friis de la *Western Electric Company* en 1922–3a por la mezurado de signala forteco ĉe Nauen, Marion, kaj New Brunswick.

La artikolo estas daŭrigota en la venonta numero.

DIVERSAĴOJ.

Resumoj kaj Aludoj.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

Dimensieco je Senfadenaj Ekvacioj.—W. A. Barclay.

La artikolo pritraktas la problemon havi ambaŭ flankojn de ekvacio samdimensie, kaj traktas pri kelkaj ekzemploj en senfadena cirkvita praktikado.

Oni montras, ke la principo de dimensieco donas utilan rimedon kontroli ekvaciojn per nura inspekto, kvankam ĝi ne estas per si sufiĉa provo de korekteco.

LIBRO-RECENZO.

Recenzoj estas donitaj de la jenaj verkoj:

Thermionic Vacuum Tube Circuits (Termionaj Vakuaj Tubaj Cirkvitoj), de L. J. Peters.

Practical Radio Construction and Repairing (Praktika Radio-Konstruado kaj Riparado), de Moyer kaj Wostrel.

Elements of Radio Communication (Elementoj de Radio-Komunikado), de W. E. W. Stone.

Electric Rectifiers and Valves (Elektraj Rektifikatoroj kaj Valvoj), de N. A. de Bruyne, tradukita el la germana de Gunterschulze.

The Four Electrode Valve (La Kvar-Elektroda Valvo), de Fred Goddard.

Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

A LOUD-SPEAKER SUBSTITUTE.

(*Convention date* (*Germany*), *22nd January*, 1926. *No.* 264811.)

A defect inherent in all known forms of diaphragm is that owing to the elasticity and distributed mass of the vibrating body the system as a whole is bound to possess one or more fundamental resonances, which are emphasised in action and so introduce distortion. It is accordingly proposed to convert electrical current variations into corresponding sound-waves without the intermediary of any mechanical vibration, apart from that of the air itself.

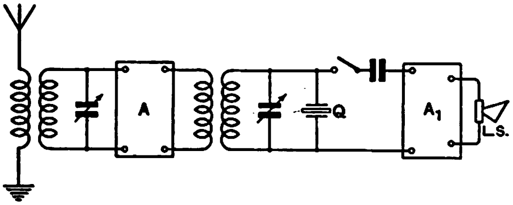
This is accomplished by utilising the brush or corona discharge from a pointed electrode. A distinction is drawn between this kind of discharge and the ordinary disruptive or spark discharge. In the former case, the current of electrified ions streaming away from the point is found to set the adjacent air into steady motion. At a certain critical pressure of the charging voltage the discharge stream becomes highly responsive to fluctuations such as can be derived from a current of acoustic frequency. An equivalent wave motion is thus communicated directly to the adjacent air, and thereby reproduces the original sound.

Patent issued to International General Electric Co.

PIEZO-CRYSTAL RECEIVERS.

(*Convention date* (*Germany*), *7th November*, 1925. *No.* 261,041.)

At certain of the fundamental longitudinal vibration-frequencies of a piezo-crystal a luminous glow is created, and can be used to give visual indication of received signals. There is a similar acoustic effect in which the crystal emits a sonorous note, which can be accentuated by means of a suitable low-frequency amplifier to operate a loud-speaker, thereby giving an audible record of incoming signals.



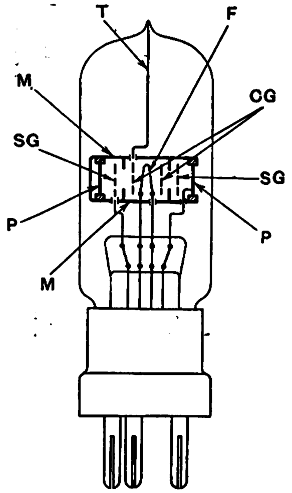
Both phenomena occur only when there is exact identity between the received signals and the fundamental crystal frequency, so that the method is ultra-selective and also largely free from the effect of atmospheric disturbances. Further, no heterodyne oscillation is necessary when the audible effect is utilised. As shown, incoming signals are amplified at *A* and applied across the crystal *Q*, which is preferably enclosed in an evacuated or gas-filled bulb. A_1 is a low-frequency amplifier feeding the sonorous crystal vibrations to a loud-speaker *LS*.

Patent issued to the Radiofrequenz Co.

SCREENED GRID VALVES.

(*Convention date* (*Holland*), *19th November*, 1926. *No.* 280,851.)

A relatively small screening-grid *SG* is interposed between a cylindrical control grid *CG* and a similarly-shaped plate *P*. In order to ensure that all the electrostatic lines of force existing between the plate and control grid shall pass through the screening-grid, metal shields *MM* are provided and surround the electrodes as shown. The shields *M* are insulated from the screening grid, but are connected to the filament or some other point of constant potential. They are supported by glass rings formed on the cylindrical plate.



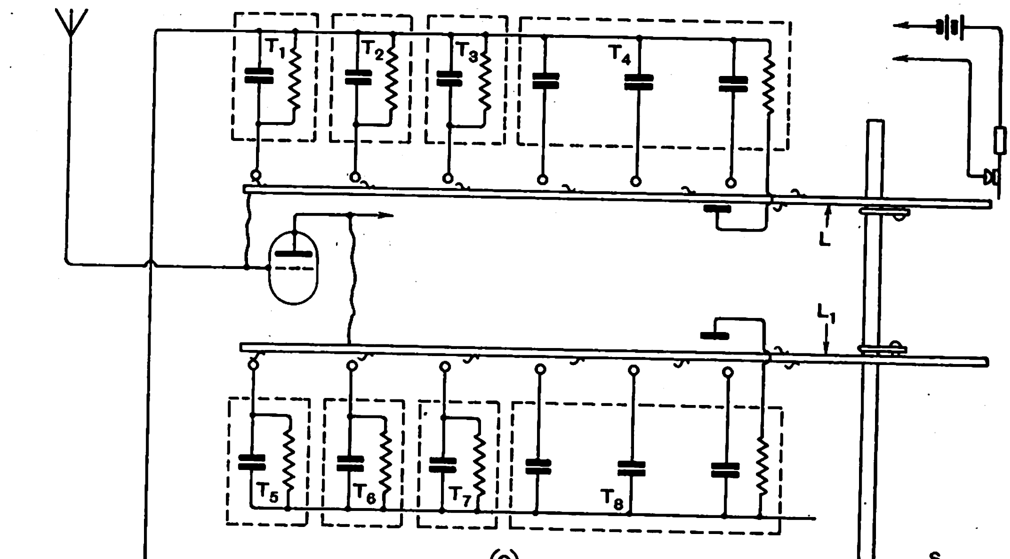
Additional metal rings formed on the shields *M* project inwardly between the control and shielding grids, in order to increase the neutralising effect. The input lead *T* for the control grid is located at the top of the bulb.

Patent issued to N. V. Philips Glowlamp Co.

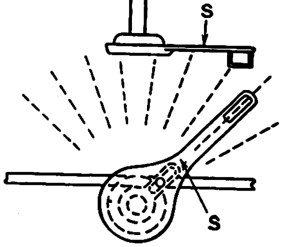
SWITCH-CONTROLLED RECEIVER.

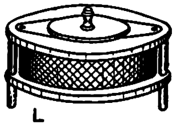
(*Application date*, *23rd March*, 1927. *No.* 284,887.)

Relates to a multivalve receiver of the kind in which the tuning is entirely controlled by switch mechanism so that a selected station can be brought in merely by setting the control knob to a definite position, as distinct from the ordinary flexible adjustment of one or more rotary condensers. In the present invention this is accomplished by mounting a number of definitely tuned circuit elements in the receiver and then selecting the desired combination.

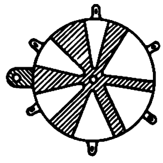


(C)





(A)



(B)

Each circuit element comprises a coil *L*, on the top of which is mounted a fixed condenser, Fig. A. A certain degree of elasticity may be provided by forming the condenser with a series of partial armatures, shown shaded in Fig. B.

In the complete receiver the various tuned elements are assembled as shown at T_1 — — T_8, Fig. C. They are brought successively into circuit by means of a series of spring contacts carried on a pair of sliding arms *L*, L_1 controlled by the master switch *S*. (The latter is also shown in elevation). The elements T_4 and T_8 utilise graded condensers of the type shown in Fig. B, the remaining elements being invariable.

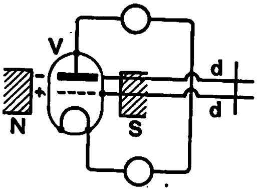
Patent issued to J. A. Baertsoen.

ULTRA HIGH-FREQUENCY GENERATORS.

(*Convention date* (*Germany*), *29th October.* *No.* 279,824.)

It has already been proposed to generate very high frequencies by causing the electrons forming the discharge stream inside a vacuum tube to vibrate individually, so that the resultant frequency is not limited by the inductance-capacity values of the external circuits. Such "internal" oscillations are created by interaction between the electron stream, a positively-charged grid, and a negatively-charged anode. In the case of gas-filled tubes, secondary effects between the electrons and adjacent gas-molecules may also be brought into play.

According to the present invention the available range of oscillations is stabilised by placing the generator tube in the field of a powerful electro-magnet N_8, which may be energised either by direct or alternating current. In this way it is also found possible to vary the internal oscillation energy within wide limits, and so to maintain the amplitude of the output oscillations fed to the wave circuit *d*, *d* at a manageable value.

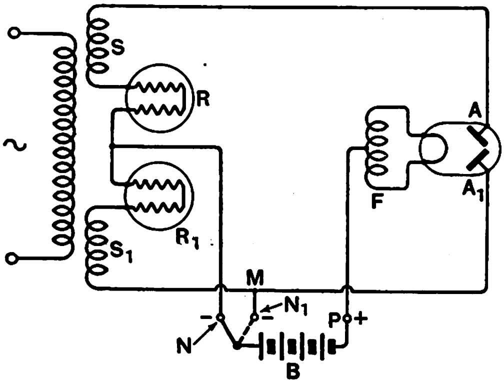


Patent issued to Dr. A. Esau.

RECTIFYING INSTALLATIONS.

(*Convention date* (*Belgium*), *29th January*, 1927. *No.* 284,306.)

The rectifier circuit is so arranged that full-wave rectification can be utilised for a low-charging voltage, with the alternative of using half-wave rectification if a higher charging-voltage is required.



When the battery B is connected across the terminals P and N, rectified current corresponding to one half-wave of the supply flows from P through the battery, variable resistance R and secondary coil S to the anode A of the rectifier, and back through the filament F to complete the circuit.

The next half-wave passes through the resistance R_1 and coil S_1 to the anode A_1, the circuit being completed as before.

For a higher charging-voltage the battery is connected across the terminals P and N_1. In this case only alternate half-waves of the supply are rectified, the circuit being from terminals P to N_1, then to point M and through coil S_1, resistances R_1, R and coil S, to the anode A, and so back through the filament F to the positive terminal P.

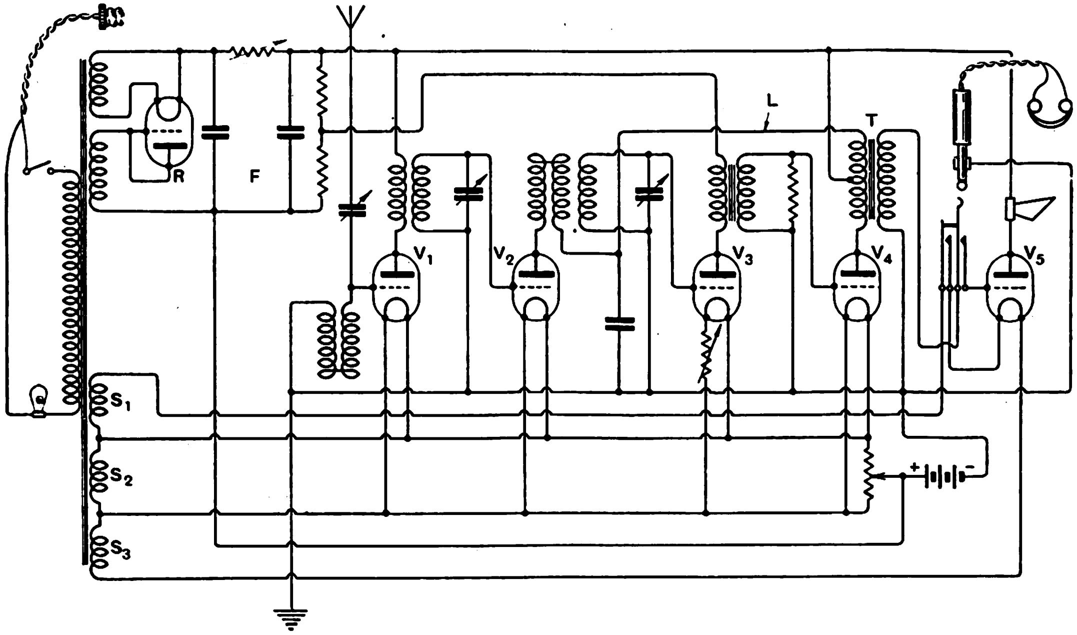
Patent issued to the N. V. Philips Glowlamp Co.

A MAINS-FED RECEIVER.

(*Convention date* (*U.S.A.*), *17th August*, 1925. *No.* 256,994.)

The Figure shows a five-valve set, comprising two stages of high-frequency amplification V_1, V_2, and a power amplifier V_5. A three-electrode tube R, with plate and grid connected, serves as a rectifier to supply the plate circuits through a filter circuit F, comprising series resistances and condensers. Unrectified current for the filaments of the first four valves is drawn directly from a section of S_2, the secondary winding, a higher-voltage supply of A.C. current for the filament of the power stage V_5 being derived from the outer terminals S_1, S_3 of the full secondary winding.

Disturbance due to the use of A.C. filament supply is largely minimised by using filaments having a high heat-inertia, *i.e.*, filaments which carry a relatively heavy current in proportion to the applied voltage. So far as the first two stages of HF amplification are concerned the discrepancy between the frequency of supply and the signal frequencies is such that little disturbance will arise here. Similarly the effect on the power amplifier is comparatively insignificant.



In the intermediate stages, hum due to the A C. supply is dealt with as follows: The plate circuit of the H.F. amplifier V_2 comprises a low-frequency path through a lead L to the upper part of the L.F. transformer T in the output of the valve V_4. The two halves of the primary of this transformer are oppositely wound, so that the disturbances from the valves V_2 and V_4 tend to balance out. The output from valves V_1 and V_5 can be similarly opposed.

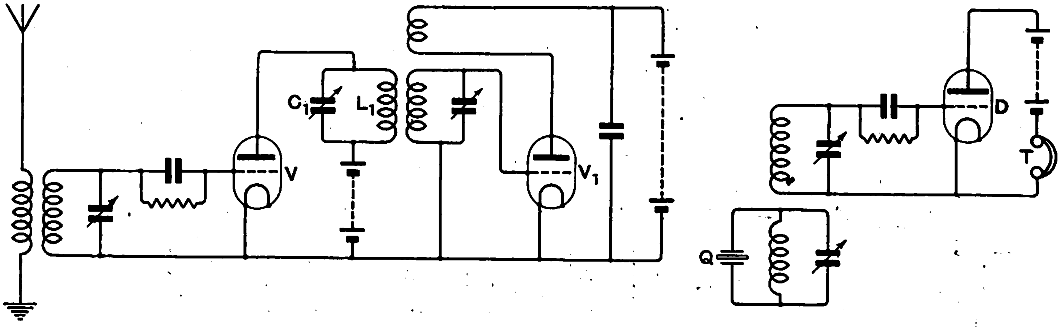
Patent issued to B. F. Miessner.

SELECTIVE RECEPTION.

(*Application date*, 11*th October*, 1926. *No.* 285,108.)

In order to ensure selectivity, advantage is taken of the fact that the amount of energy absorbed by a resonant device, or circuit, coupled to a high-frequency generator depends upon the approximation of the frequency of the absorber to that of the oscillator. Consequently, any change in the frequency of one, if sufficiently rapid, can be indicated by the action of the other, say upon a rectifying valve feeding a telephone or other recording device.

As shown in the Figure, incoming signals are fed through an amplifier V to a circuit C_1, L_1 tuned approximately to the frequency of an oscillating valve V_1. The valve V may be regarded as a variable resistance across the circuit C_1, L_1, so that the amount of energy absorbed by the latter from the oscillator V_1 will depend upon the plate current of V, *i.e.*, upon the strength of the incoming signals.



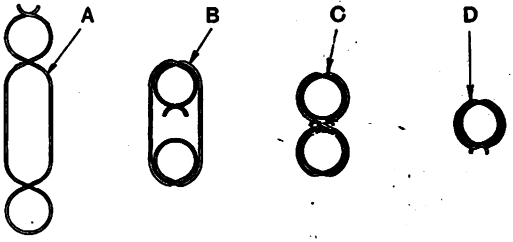
A piezo-electric crystal Q is coupled to the grid circuit of a detector valve D, which is also coupled to the plate coil of the oscillator V_1. If the frequency of valve V_1 is normally adjusted to that of the crystal Q, when no signals are being received, then there will be maximum absorption by the crystal. The effect of incoming signals, by altering the frequency of V_1, reduces absorption by the crystal Q and so operates the telephones T in the plate circuit of the detector D.

Patent issued to J. Robinson.

COIL-WINDINGS.

(*Application date*, 17*th January*, 1927. *No.* 286,047.)

A method of winding inductance coils, in which the external field of the completed coil is stated to remain approximately the same as that of the original straight wire, is illustrated in the Figure. The formation A is obtained from a single circular loop by twisting it locally at each end of a diameter. By bending inwards each of the small loops the stage B is reached. This is then twisted sideways to give C. The two remaining loops are then bent one over the other to complete the coil as shown at D. The finished coil is suitably mounted in a holder. The self-capacity of the winding is admittedly high.



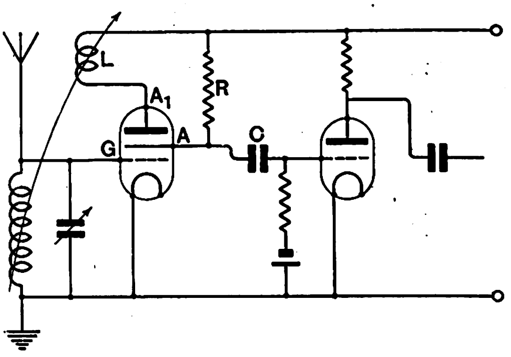
Patent issued to F. Rogers and E. H. Griffiths.

FOUR-ELECTRODE VALVES.

(*Application date*, 23*rd November*, 1926. *No.* 285,975)

A four-electrode valve is employed in order to introduce reaction in a resistance-coupled circuit where the value of the plate resistance is normally too high to permit of this being done with the standard type of valve. The main anode A is connected to the high-tension through a resistance R of 5 megohms, the coupling circuit being completed through a condenser C as usual.

The reaction coil L is inserted in series with the second anode A_1, and is back-coupled to the aerial. The valve is so constructed that the portion of the cylindrical grid G, which lies between the filament and the inner and outer anodes A, A_1, is of coarser mesh than the remainder of the grid.



Patent issued to The Edison Swan Electric Co.

EXPERIMENTAL
WIRELESS
& The WIRELESS ENGINEER

VOL. V. JUNE, 1928. No. 57.

Editorial.

The Equivalent Inductance and Capacity of an Aerial.

A VERTICAL wire connected to the earth at its lower end has a certain natural frequency of oscillation. An infinite number of oscillatory circuits could be made up to have the same natural frequency, the only necessary condition being that the product of the inductance and the capacity must be constant. Only one of these circuits, however, could be regarded as equivalent to the aerial and one practical test of this equivalence consists in finding the effect on the natural frequency of a variation of the inductance or capacity. In the case of the aerial it is assumed that the variation is produced by the insertion of an inductance or a condenser between the foot of the aerial and the earth; the simple oscillatory circuit in which the insertion of the same inductance or condenser produces exactly the same change of natural frequency can be regarded as equivalent to the aerial, and its inductance and capacity as being the equivalent inductance and capacity of the aerial.

If now the aerial be regarded as a transmission line, one may as an approximation assume it to have a constant inductance and capacity per unit length and from these values it is possible to calculate its equivalent inductance and capacity as above defined. In the Marconi "Year Book of Wireless Telegraphy and Telephony" for 1917 we described this in some detail and carried out the calculation. If the height of the aerial is h and the inductance and capacity per unit length L and C respectively, we showed that the equivalent inductance $L_0 = hL/2$ and the equivalent capacity $C_0 = 8hC/\pi^2$. We also deduced approximate expressions for the somewhat elusive values of the inductance and capacity per unit length of such a transmission line, and thus, if r is the radius of the wire, showed that

$$L_0 = h \log_e \frac{h}{r} 10^{-9} \text{ henries,}$$

and $$C_0 = \frac{1}{2.22} \cdot \frac{h}{\log_e \frac{h}{r}} \mu\mu \text{F.}$$

In a recently published textbook entitled "Wireless Principles and Practice," by L. S. Palmer, a review of which appears on p. 338 of this number, a different result is obtained. It is stated on page 55 that the aerial reactance may be regarded as due to a capacity hC and to an inductance slightly larger than $hL/3$, the final value being given as $hL/2.46$. Since the underlying assumptions appear to be the same, it is interesting to examine how two different answers can be obtained to what appears to be a simple definite question, viz.: if a transmission line of length h has inductance L and capacity C per unit length, what must be the inductance L_0 and the capacity C_0 of a simple oscillatory circuit which has the same resonant frequency and which has the same change of resonant frequency when a small inductance or capacity is inserted?

In the case of the simple circuit let the inductance be increased by an amount L_x, then the resonant wavelength will be increased from λ_0 to λ, where

$$\frac{\lambda^2}{\lambda_0^2} = \frac{L_0 + L_x}{L_0}$$

If we put $f/f_0 = \lambda_0/\lambda = a = 1 - \delta$, then for a small added L_x, a will be slightly less than 1, δ will be a small fraction, and

$$1 + \frac{L_x}{L_0} = \frac{1}{a^2} = \frac{1}{(1-\delta)^2} = 1 + 2\delta$$

to a closer and closer degree of approximation as L_x is made smaller. Hence for very small values of L_x/L_0 we have

$$L_0 = \frac{L_x}{2\delta}$$

where $\delta = 1 - f/f_0 = \dfrac{f_0 - f}{f_0} =$ the proportional decrease of resonant frequency on inserting L_x.

Now, turning to the aerial or transmission line, it is shown in textbooks on the subject that the apparent impedance of such a line as measured at the sending end, that is, at the foot of the aerial, is given by the formula

$$\sqrt{\frac{L}{C}} \cdot \frac{1}{j \tan \omega h \sqrt{LC}} \text{ ohms}$$

where h is the length of the line or height of the aerial, and L and C are in henries and farads respectively.

The resonant frequency is the frequency which makes this impedance zero, that is, which makes $\omega h \sqrt{LC}$ equal to $\pi/2$. Let us call this $f_0 = \omega_0/2\pi$.

If now an inductance L_x be inserted at the sending end, the frequency necessary to reduce the total impedance to zero will be changed to $f = \omega/2\pi$. The total impedance is now

$$j\omega L_x + \sqrt{\frac{L}{C}} \cdot \frac{1}{j \tan \omega h \sqrt{LC}} \text{ ohms,}$$

and since this is to be zero,

$$L_x = \frac{1}{\omega}\sqrt{\frac{L}{C}} \cdot \frac{1}{\tan \omega h \sqrt{LC}} \text{ henries.}$$

When an angle differs slightly from $\pi/2$, its cotangent is approximately equal to the small angle by which it differs from $\pi/2$; hence, since $\omega_0 h \sqrt{LC} = \pi/2$,

$$\begin{aligned} L_x &= \frac{1}{\omega}\sqrt{\frac{L}{C}} \, . h\sqrt{LC} . (\omega_0 - \omega) \\ &= \frac{\pi}{2} \cdot \sqrt{\frac{L}{C}} \cdot \frac{\omega_0 - \omega}{\omega\,\omega_0} \\ &= \frac{\pi}{2} \cdot \frac{\delta}{\omega} \sqrt{\frac{L}{C}} \, . \end{aligned}$$

Comparing this with the formula $L_0 = \dfrac{L_x}{2\delta}$ found above for the simple circuit, we see that if a given L_x is to produce the same δ in each case,

$$L_0 = \frac{\pi}{4\omega}\sqrt{\frac{L}{C}} \text{ henries}$$

and $$C_0 = \frac{1}{\omega^2 L_0} = \frac{4}{\pi\omega}\sqrt{\frac{C}{L}} \text{ farads.}$$

If L_x/L_0 is very small, ω is approximately equal to ω_0 in these equations, and assuming that the natural wavelength is four times the height of the aerial, and putting

$$f_0\lambda = 3 \times 10^{10};$$

then $$L_0 = \frac{\pi}{4\omega_0}\sqrt{\frac{L}{C}} = \frac{h}{6 \times 10^{10}}\sqrt{\frac{L}{C}} \text{ henries.}$$

and $$C_0 = \frac{4}{\pi\omega_0}\sqrt{\frac{C}{L}} = \frac{8h}{\pi^2} \cdot \frac{1}{3 \times 10^{10}} \cdot \sqrt{\frac{C}{L}} \text{ farads.}$$

It is very difficult to decide what values should be taken for the inductance and capacity per unit length of a vertical wire of height h and radius r, but in the article in the "Year Book" of 1917 we showed that as a close approximation it can be assumed that

$$L = 2 \log_e \frac{h}{r} \, . \, 10^{-9} \text{ henries per cm.}$$

and $$C = \frac{1}{2 \log_e \dfrac{h}{r}} \cdot \frac{1}{9 \times 10^{11}} \text{ farads per cm.}$$

whence $LC = \dfrac{1}{9 \, . \, 10^{20}}$, which must, of course, be true however we determine L and C.

Inserting this value in the formulæ for L_0 and C_0, we obtain

$$L_0 = \frac{hL}{2} \text{ and } C_0 = \frac{8}{\pi^2} hC,$$

which are independent of our approximations for L and C.

On inserting the approximate values for L and C we obtain

$$L_0 = h \log_e \frac{h}{r} \, . \, 10^{-9} \text{ henries}$$

and $$C_0 = \frac{1}{2.22} \cdot \frac{h}{\log_e \frac{h}{r}} \cdot \mu\mu\text{F}.$$

as the equivalent inductance and capacity of the earthed vertical wire.

It was shown in the "Year Book" that the same results are obtained by assuming that a condenser is inserted at the foot of the aerial.

We shall now examine the method by which Dr. Palmer arrives at a different result. If, instead of adding a small inductance L_x, one changes the frequency from the resonant value f_0 to some other value f, the reactance changes from zero to an amount which should be the same for the aerial and its equivalent circuit. In a simple circuit with inductance L_0 and capacity C_0, the reactance becomes $j\left(\omega L_0 - \frac{1}{\omega C_0}\right)$ or $j\omega_0 L_0\left(\frac{\omega^2 - \omega_0^2}{\omega\omega_0}\right)$. In the aerial it becomes

$$X = \sqrt{\frac{L}{C}} \cdot \frac{1}{j \tan \omega h\sqrt{LC}}$$
$$= -j\sqrt{\frac{L}{C}} \cdot \text{cotan } \omega h\sqrt{LC}.$$

Now $$\text{cotan } x = \frac{1}{x} - \frac{x}{3} - \frac{x^3}{45}, \text{ etc.}$$

Hence

$$X = -j\sqrt{\frac{L}{C}}\left\{\frac{1}{\omega h\sqrt{LC}} - \frac{\omega h\sqrt{LC}}{3} - \frac{(\omega h\sqrt{LC})^3}{45}, \text{ etc.}\right\}$$

which may be written

$$X = j\sqrt{\frac{L}{C}}\left\{\omega \cdot \frac{h\sqrt{LC}}{3}\left(1 + \frac{\omega^2 h^2 LC}{15}\right) - \frac{1}{\omega h\sqrt{LC}}\right\}$$

On comparing this with the formula for the reactance of the equivalent circuit, it is seen that it is somewhat similar in form, but unfortunately the term $\frac{\omega^2 h^2 LC}{15}$ is by no means negligible and varies as the square of the frequency. At resonance $\omega_0 h\sqrt{LC} = \pi/2$, so that $\omega_0^2 h^2 \, . \, LC/15 = \frac{1}{6}$. It must be remembered that the quantity in brackets is the small difference between two large reactances, and instead of one of them being directly proportional to ω and the other inversely proportional to ω as in the equivalent circuit, there is this disturbing term depending on ω^3 which makes it very difficult, if not impossible, to derive from a comparison of the equations any conclusion as to the values of the equivalent inductance and capacity. This is the reason for the erroneous result obtained by Dr. Palmer.

The correct result can, however, be obtained from the consideration of the effect of changing the applied frequency in the following manner. In a simple oscillatory circuit, $X = \omega L_0 - \frac{1}{\omega C_0} = \omega_0 L_0\left(\frac{\omega^2 - \omega_0^2}{\omega\omega_0}\right)$ and the change of reactance with frequency is found by differentiating, thus

$$\frac{dX}{d\omega} = L_0\left(1 + \frac{\omega_0^2}{\omega^2}\right).$$

In the neighbourhood of resonance $\omega = \omega_0$, and $dX/d\omega = 2L_0$.

In the case of the transmission line or aerial the apparent reactance is

$$-\sqrt{L/C} \, . \, \text{cotan } \omega h\sqrt{LC}$$

and the change of reactance with frequency is

$$\frac{dX}{d\omega} = \sqrt{\frac{L}{C}} \cdot \frac{1}{\sin^2 \omega h\sqrt{LC}} \cdot h\sqrt{LC}.$$

In the neighbourhood of resonance $\omega = \omega_0$ and $\omega_0 h\sqrt{LC} = \pi/2$, whence

$$dX/d\omega = hL.$$

Hence, if the equivalent circuit is to have the same value of $dX/d\omega$ as the aerial, $L_0 = hL/2$, as already found by the method of adding inductance.

The Apparent Demodulation of a Weak Station by a Stronger One.

By R. T. Beatty, M.A., B.E., D.Sc.

Introduction.

WHEN a stage of high-frequency amplification is used in a receiver a resonance curve can be drawn for the tuned circuit which gives by inspection the ratio of the amplification of an unwanted station to that of the station which is tuned in. For a tuned circuit (Fig. 1) a resonance curve (Fig. 2) can be drawn in which the voltage amplification at resonance is taken as unity. n is the resonance frequency; δn is the frequency difference between the wanted and unwanted stations, and $m = L \,.\, 2\pi n/r$* (reactance of coil divided by its high-frequency resistance).

If the coil is wound in a single layer with solid wire on a 2in. former its value of m at broadcast frequencies will be about 100. Let the frequency n of the wanted station be 1,000 kilocycles, and suppose that the unwanted station is 50 kilocycles distant and of strength equal to that of the wanted station. Then $2m \,.\, \delta n/n = 2 \times 100 \times 50/1000 = 10$; hence from the curve $y = 0.1$, which means that the strength of the unwanted station has been reduced to one-tenth. Similarly, if the unwanted station is 200 kilocycles off tune we get $y = 0.025$.

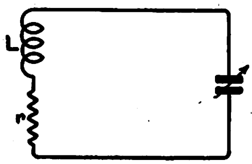


Fig. 1.

But to eliminate interference completely we should have to cut down the off tune station much more drastically than this: a value of 0.0001 for y would be none too small. It would seem then from elementary theory that with the above circuit (which is a good average one for H.F. amplification) selectivity should be very poor indeed.

Actually, however, we know that with such a circuit we can select between two equally strong stations 50 kilocycles apart, and with the use of reaction the off tune station can be eliminated even though its strength at the receiving aerial is ten times that of the other. There must accordingly be some mutual action between the signals from the two stations which has not been taken into account in the simple theory of the tuned circuit.

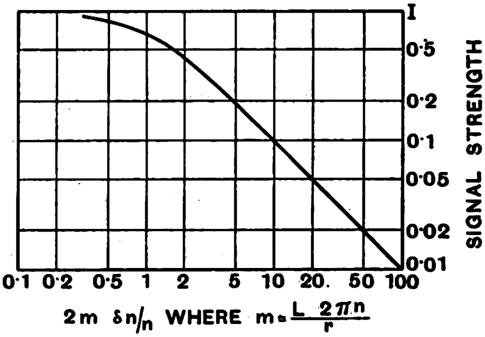


Fig. 2.

Supersonic Beats Between the Carrier Waves.

The cause of the unexpectedly selective behaviour of the circuit lies in the nature of the supersonic beats between the carrier waves of the two stations.* The amplitude of the modulated wave from the unwanted station may be written

$$U \,.\, \cos 2\pi nt + M \,.\cos 2\pi nt \,.\cos 2\pi at$$

where U and M are the carrier and modulation amplitudes, n is the carrier frequency, and a is the modulation frequency. The peak carrier amplitude occurs when $\cos 2\pi nt = 1$, and hence the corresponding amplitude of the envelope is

---

* This method of plotting the resonance curve for a single tuned circuit gives a single resonance curve which can be used for any values of L, r, and n. It is accurate provided that the value of m remains constant as the incoming frequency moves away from the frequency to which the circuit is tuned. This proviso limits the use of the curve to valves of $\delta n/n$ not exceeding about 0.2.

* Though the phenomenon is known in a general way to radio engineers I have not been able to find any mathematical treatment of it in the literature: a qualitative account was given by Round in the *Wireless Weekly* in 1921, and mention is there made of its use by Franklin in duplex telephony.

$$U + M . \cos 2\pi at.$$

Fig. 3 shows that this is the sum of U and the projection on the horizontal of a vector M which rotates a times per second, and the amplitude of the envelope varies between $U + M$ and $U - M$. In Fig. 4 U is drawn to represent one peak volt and M is an amplitude of modulation of 0.2 peak volt: we may imagine that while U remains of unit length its left extremity slides to and fro at audio frequency on the horizontal diameter of the circle. As shown in the lower part of Fig. 4, the envelope when referred to its centre line will be a wave of amplitude M.

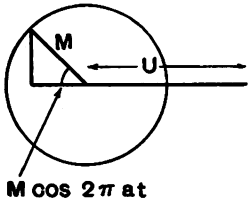


Fig. 3.

Next consider a pure carrier wave from the unwanted station U and a weaker one from the wanted station W. The resultant is

$$U . \cos 2\pi nt + W . \cos 2\pi(n+s)t$$

where s is the (supersonic) frequency difference between the two waves. Considering peak values only of U ($\cos 2\pi nt = 1$) we get

$$U + W . \cos 2\pi st$$

which represents (Fig. 5) the sum of U and the projection on the horizontal of a vector W rotating s times per second: the envelope is a wave of frequency s.

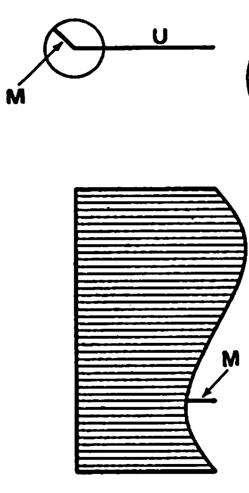


Fig. 4.

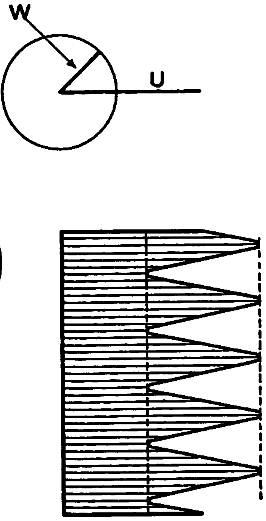


Fig. 5.

Fig. 6 shows the result when U is modulated; it is obtained by combining Figs. 4 and 5.

Since W is rotating much more rapidly than M, the amplitude of the U envelope will remain at $U + M \cos 2\pi at$, while W executes a few rotations and the whole amplitude will vary between

$$\left.\begin{array}{ll} & U + M \cos 2\pi at + W \\ \text{and} & U + M \cos 2\pi at - W \end{array}\right\} \quad .. \quad (1)$$

while the average as shown by the dotted line in Fig. 6 is $U + M \cos 2\pi at$.

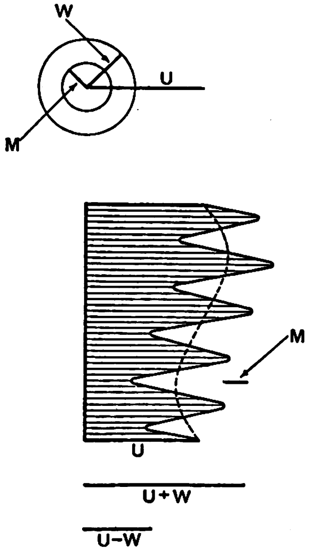


Fig. 6.

Case when W is Greater than U + M.

Since the amplitude can never become negative we must re-write (1) as

$$\left.\begin{array}{ll} & W + U + M \cos 2\pi at \\ \text{and} & W - U - M \cos 2\pi at \end{array}\right\} \quad .. \quad (2)$$

the average of which is W.

Fig. 7 shows this result: the straight dotted line is the average amplitude, and the peaks are symmetrically arranged on either side.

Effect Due to a Straight Line Detector.

When the voltages whose wave forms are shown in Figs. 6 and 7 are applied to the grid of an anode bend detector whose A.C. characteristic is a straight line, the envelopes indicated by curves 1 and 2 (Fig. 8) are rectified and produce A.C. voltages at the plate of supersonic frequency with audio modulation as in curves 1*a* and 2*a*. The supersonics can be eliminated by insertion of a stopper circuit, and in any case can produce no effect in the loud speaker, so that the final result will be the central wavy dotted line in curve 1*a* (when W is smaller than U) or the central straight dotted line in 2*a* (when W is greater than U).

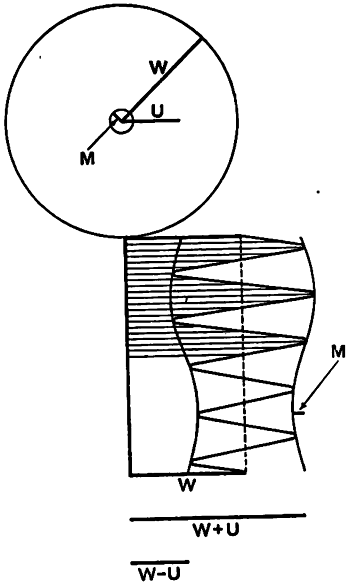


Fig. 7

It appears, therefore, that with a perfect detector the unwanted station would be completely demodulated by the slightly stronger wanted station, and it is easily seen that audio modulation of the wanted station would be unaffected by the carrier wave of the unwanted, since the length of W in Fig. 7 would then vary at audio frequency so that the centre dotted line would become wavy with an amplitude independent of the magnitude of U.

Effect Due to an Imperfect Detector.

The A.C. characteristic of an actual anode bend detector is shown in Fig. 9. We assume that by H.F. amplification one volt (peak value) due to the carrier of the wanted station is impressed on the grid of the detector: then if $U = W/2$ and if the modulation of U is 20 per cent., the plate volts will vary at audio frequency between the average of P and P_1 and the average of Q and Q_1. The average of Q and Q_1 is $(8 + 0.72)/2 = 4.36$, and the average of P and P_1 is $(6.6 + 1.42)/2 = 4.01$. The difference between these is 0.35 volt, and this is the resultant audio frequency variation due to the unwanted station. If the characteristic had been a straight line between these limits the audio variation would have disappeared completely. If $U = W/5$ the corresponding strips are P_2Q_2 and P_3Q_3, and the difference between the average values of P_2 and P_3 and of Q_2 and Q_3 is 0.08 volt. Finally, if $U = W/10$ the strips P_4Q_4 and P_5Q_5 are both on the straight part of the characteristic, so that the mean value of P_4 and P_5 is equal to the mean value of Q_4 and Q_5: that is, the modulation of the unwanted station has disappeared as in the case of the straight dotted line in Fig. 7. This ratio between the strengths of the two stations of 10 : 1 agrees in a general way with the ratio found necessary in practice.

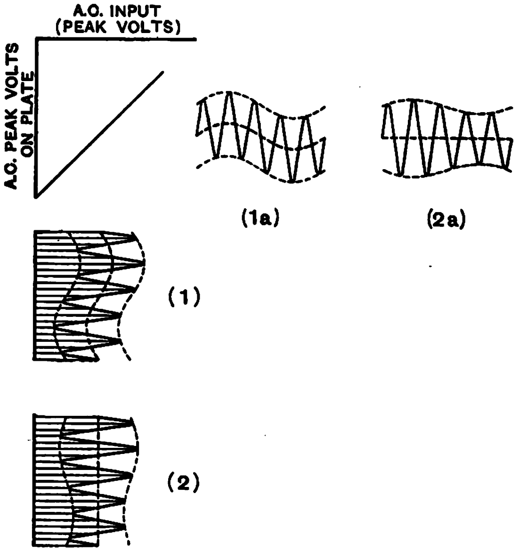


Fig. 8

Analogy with the Superheterodyne.

A little reflection will show that the effects described above are those which are produced in a superheterodyne when a local oscillation is made to beat with the incoming signal: the wave carried through the intermediate amplifier is of the type in Fig. 7: the audio component is borne on a supersonic carrier and can only be isolated by passing through a second detector.

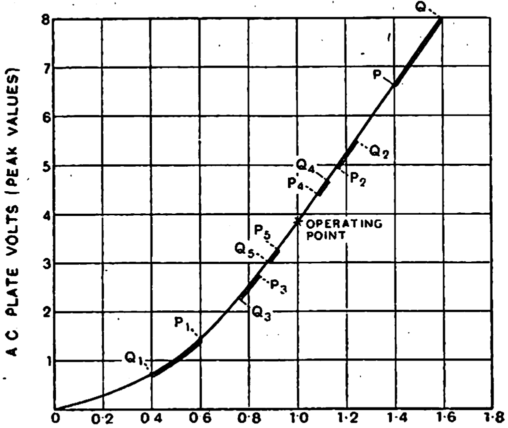
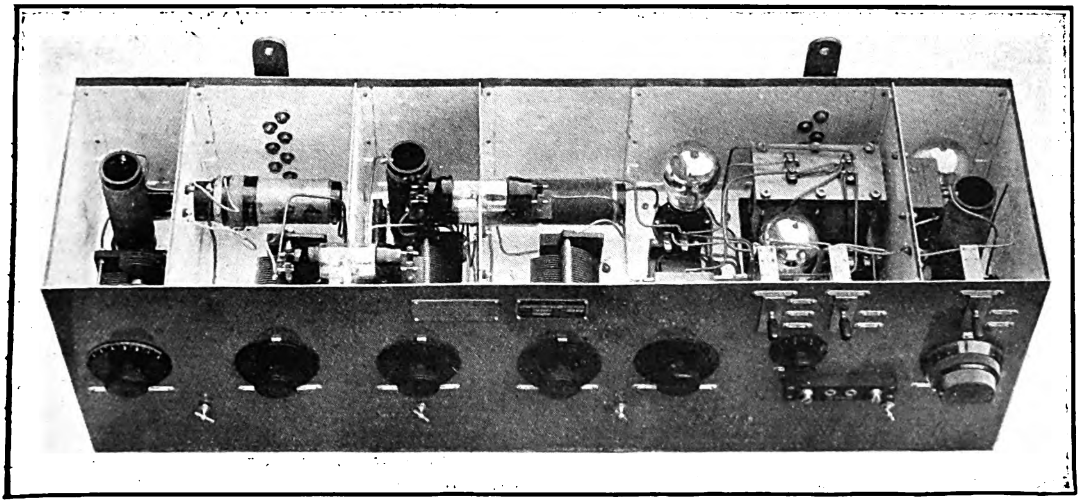


Fig. 9

Conclusion.

A resonance curve (Fig. 2), though giving information as to the relative amplification of the CARRIER WAVES of the tuned-in station and the station off tune, does not give the relative amplification of the MODULATION: the latter depends on the curvature of the detector A.C. characteristic and the position of the operating point. With a truly linear A.C. characteristic the unwanted station would be silenced if its carrier were slightly weaker than that of the wanted station. Actual A.C. characteristics, however, almost invariably have an initial curvature, and it is necessary that neither of the two strips shown in Fig. 9 should lie on the curved portion. In practice it is found that the unwanted station can be silenced if its carrier wave does not exceed one-tenth that of the wanted station as measured at the grid of the detector valve.

New Naval Apparatus.



The Marconi Co. have recently introduced a new series of interesting receivers specially designed or naval service. Above is an interior view of one of these sets, which includes two screened-valve H.F. stages and a new form of partial gang control.

Short-wave Aerial Systems.

An Elementary Theory of the Transmission of High-frequency Energy along the Feeders.

By E. Green, M.Sc.

IN connection with the beam system and other systems of short-wave radio-telegraphy, it is necessary to supply the high-frequency energy through cables usually called feeders, several wavelengths long. In the beam system these feeders consist of concentric copper tubes, the inner tube being supported on porcelain insulators, so that the attenuation is very small. The theory of wave propagation in cables has been developed in many text-books in a complicated mathematical form suitable for application to the problems of cable telegraphy and telephony. The solutions so obtained can, of course, be simplified to deal with the problems that arise in the wireless case, but the author thought it worth while to develop a simpler treatment that should still be adequate. The author takes this opportunity of thanking the Marconi Company for permission to publish these notes which were developed in their service.

The first part of this treatment is based on that originally given by Heaviside in Vol. I "Electro Magnetic Theory" in the chapter on plane waves. There it is shown that the transmission of electro-magnetic disturbance along cables is analogous to the propagation of plane electro-magnetic waves in free space. We will therefore describe the simplest type of plane electro-magnetic wave, and two of their fundamental properties.

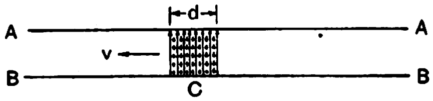


Fig. 1.

In Fig. 1, *A* and *B* are two infinite, parallel, and perfectly conducting planes at any distance apart. The type of wave to be considered is shown at *C*, and consists of a thin sheet (thickness *d*) within which there is uniform intensity of electric force *X* (shown by the vertical lines) and the corresponding intensity of magnetic force at right angles to the plane of the paper. Theory shows that this sheet moves through the dielectric between the planes *A B* with the velocity v characteristic of electro-magnetic waves in that dielectric. If μ is the magnetic permeability and k the specific inductive capacity of the dielectric

$$v = \frac{3 \times 10^{10} \text{ cm per second}}{\sqrt{\mu k}}.$$

In a true electro-magnetic wave, of which that described above is a type, half the total energy is in the form of electric strain, and half in the form of magnetic strain. So that per unit volume we have

$$\frac{kX^2}{8\Pi} = \frac{\mu H^2}{8\Pi}.$$

Now provided there is no loss of energy in the medium or in the bounding planes *A B*, this equality of the two forms of energy persists. In this case the law of propagation of the disturbance is a simple one, *i.e.*, the wave sheet suffers no change in character but moves forward with the steady velocity v.

It will appear at a distance x further along at a time $\frac{x}{v}$ later in its original form, as a wave sheet of thickness d and uniform electric intensity X. We can build up any complex wave of a series of such elementary sheets, and each will preserve its independence so that the whole complex wave travels with velocity v without change of form, that is, it is propagated without distortion.

Let us now apply these ideas to the transmission of electro-magnetic disturbances along feeders.

The feeder is assumed to be of infinite length, and may consist of a pair of parallel wires, or concentric cylinders.

Let

L = inductance of feeder in henries per unit length (go and return).

C = capacity in farads per unit length.

μ = magnetic permeability of the dielectric between the conductors.

K = specific inductive capacity of same.

v = velocity of propagation of electromagnetic disturbance along the feeder.

Infinitely Long Feeder of Negligible Resistance and Leakage.

In Figs. 2(*a*) and (*b*), *A* and *B* represent the two conductors of a feeder. If an E.M.F. *E* is applied across the input end of the feeder, as shown in Fig. 2(*a*), it immediately charges up the initial portion of the feeder to this potential difference, and these charges with the corresponding lines of stress between them commence to move down the feeder with velocity *v*.

If the E.M.F. is removed after a short time *dt* no more charge enters the feeder, but that already existing continues to move along the feeder by virtue of its momentum with velocity *v*, as shown in Fig. 2(*b*). Regarded from the point of view of the dielectric (in which all the energy is located) it constitutes an approximately plane-electromagnetic wave sheet of the thickness *v dt*. It is therefore analogous to the wave sheet previously considered, but the guiding conductors *A* and *B* of the feeder take the place of the bounding planes. Hence all the remarks made concerning the plane wave sheet apply (with minor modifications) to the wave sheet in the feeder.

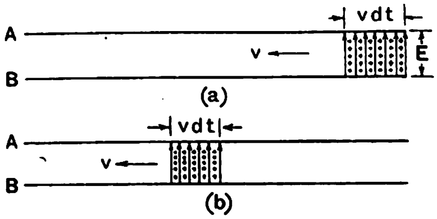


Fig. 2.

Hence :

(1) The energy in the electric field in the wave sheet is equal to that in the magnetic field.

(2) The wave sheet moves along the feeder without change in type at the constant velocity *v*. Therefore if the input E.M.F. varies in any prescribed manner, we shall have a continuous wave travelling along the feeder without change of type, and reproducing at any point the corresponding variations of the input E.M.F. at a time $\frac{x}{v}$ later, where x is the distance of the point in question from the input terminals. Or in other words, electro-magnetic waves travel down such a feeder without attenuation or distortion.

Relations of Current, Voltage and Energy in the Wave Sheet in the Feeder.

At the input end, in the time *dt* when the E.M.F. is applied, a length *v dt* is charged to the potential *E*.

$\therefore$ charge entering feeder in time

$$dt = ECv\,dt.$$

$\therefore$ current entering feeder $= ECv = I$.

However the input E.M.F. varies, this relation must hold between the instantaneous values of *E* and *I*. The feeder behaves as a non-inductive resistance value $R_0 = \frac{E}{I} = \frac{1}{Cv}$, and could be replaced by such a resistance so far as the external supply is concerned. The same relation will hold between voltage and current at any section of the wave. Hence current and voltage are in phase at any point in the feeder.

In unit thickness of the wave sheet the electric energy is $\frac{1}{2}CE^2$ and the magnetic energy is $\frac{1}{2}LI^2$.

$\therefore$ total energy $= \frac{1}{2}LI^2 + \frac{1}{2}CE^2$

But the total energy supplied from the source to unit thickness

$$= \frac{EI}{v} = E^2C$$

$$\therefore \quad CE^2 = \tfrac{1}{2}LI^2 + \tfrac{1}{2}CE^2$$

$$\therefore \quad \tfrac{1}{2}LI^2 = \tfrac{1}{2}CE^2$$

i.e., the magnetic energy is equal to the electric energy, as it should be in an electro magnetic wave.

From this last equation we get another expression for R_0

$$R_0 = \frac{E}{I} = \sqrt{\frac{L}{C}}.$$

The quantity R_0 is known as the surge impedance of the feeder, since it is the instantaneous load which even a finite feeder offers to a suddenly applied E.M.F.

From $R_0 = \sqrt{\dfrac{L}{C}} = \dfrac{1}{Cv}$

we find $v = \dfrac{1}{\sqrt{LC}} = \dfrac{3 \times 10^{10}}{\mu K}$

by substituting the calculated values of L and C.

This is the theoretical velocity of electromagnetic waves in a medium of magnetic permeability μ and specific inductive capacity K.

Infinite Feeder with Sinusoidal E.M.F. ($E_0 \sin \omega t$) applied to the Input Terminals.

We have seen that the input current will be in phase with the E.M.F. and will be

$\dfrac{E_0}{R_0} \sin \omega t = I_0 \sin \omega t$, where $R_0 = \sqrt{\dfrac{L}{C}}$

and the waves travel down the feeder with velocity $v = \dfrac{1}{\sqrt{LC}}$, so that at a distance x from the input terminals we shall have

$$E_x = E_0 \sin \omega \left(t - \frac{x}{v}\right)$$

$$I_x = I_0 \sin \omega \left(t - \frac{x}{v}\right).$$

From this we see that at points separated by a distance x given by

$$\frac{\omega x}{v} = 2\pi$$

the phase of the wave will be the same. This gives

$$x = \frac{v}{n} = \frac{1}{n\sqrt{LC}} = \lambda$$

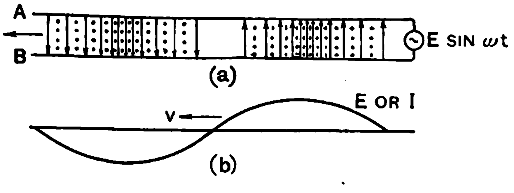


Fig. 3.

where n is the frequency; λ is therefore the wavelength of the disturbance in the feeder. With air insulation this will not differ greatly from the wavelength in free space.

Diagrammatic representation of the series of waves travelling down the cable is shown in Fig. 3(*a*) and (*b*).

Steady Conditions in Finite Feeder with a Sinusoidal E.M.F. at the Input End and Various Terminal Loads.

Surge Impedance—Non-Reflective Resistance.

Case I. **Terminal Load a Pure Resistance = R_0.**

We saw that a uniform feeder of infinite length was equivalent so far as the applied E.M.F. was concerned to a non-inductive resistance $= R_0 = \sqrt{\dfrac{L}{C}}$, known as the surge impedance. It follows therefore that if we cut such a feeder at any point and the remainder of the feeder is replaced by a resistance of this value as shown in Fig. 4, the conditions obtaining in the first part of the feeder will not be affected, *i.e.*, there will be a wave travelling down the feeder from the input end, and the whole of its energy will be absorbed in the terminal resistance R_0 without reflection. When transmitting power down a feeder several wavelengths long it will therefore be most efficient to arrange the conditions at the output terminals to give the equivalent of this resistance R_0, otherwise, as noted later, part of the wave will be reflected back and there will be bigger currents and voltages on the feeder resulting in greater losses.

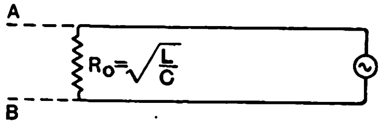


Fig. 4.

Case II. **Terminal Load not equal to R_0.**

In the case of "free" electro-magnetic waves meeting a boundary where the medium changes, we know that the waves are so reflected as to fulfil both the boundary conditions and the conditions applying to waves in the medium. Thus if the boundary is a perfect conductor it gives rise to such a reflected wave that the resultant voltage at the conducting surface is zero.

The same thing occurs to the bound waves in a feeder when the terminal load is not R_0. This case is shown in Fig. 5(*a*), where the terminal load is a resistance R in series with a reactance X. A sinusoidal E.M.F. at the input end of the feeder starts a train of waves down the feeder, and when the output end is reached a reflected wave is set up and travels back to the input end, there to be partly absorbed and partly reflected once more, until gradually a steady state is built up. In every case the reflected wave must be such as to satisfy two conditions.

(1) The relation of voltage and current in the load is determined by the impedance of the load in the normal way $\overline{V} = \overline{(R + jX)\,I}$.

(2) Any wave travelling along the feeder must have voltage and current in phase and

$$\frac{V}{I} = R_0.$$

The steady condition at the output end is thus made up of an infinite series of advancing waves, each of which is affected similarly as regards division of current between the reflected wave and the load, and also as regards phase shift. We can therefore treat the two series of waves as a single resultant incident wave giving rise to a single resultant reflected wave, and a resultant current in the load, which can be calculated by the ordinary laws of reflection.

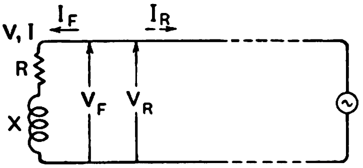


Fig. 5a.

Then the whole disturbance at any point of the feeder is the sum of these two resultant waves.

A simpler way of regarding the problem is this. Let the input terminals be at infinity. Then we can have an infinite train of sinusoidal waves advancing down the feeder, supplying current to the output circuit and being partially reflected. Then, once the reflected wave is passing a point in the feeder, the steady state will be established at all points between that point and the output terminals. There will be a definite relation between I and V at that point as regards amplitude and phase, and if we cut the feeder there and provide these values of I and V from any combination of reactance and resistance with the necessary internal E.M.F., this steady state will be maintained.

If $\frac{\overline{V}}{\overline{I}} = R_x + jX_x = Z_x$, Z_x may be called the equivalent impedance of the load and feeder at this point. From this we see that the *relative* values of I and V and their phase relation at any point are determined entirely by the nature of load and the surge impedance of the feeder, and not at all by the input end. The absolute values of I and V, however, are determined by the E.M.F .at the input end, and the equivalent impedance of the load and feeder at the transmitter.

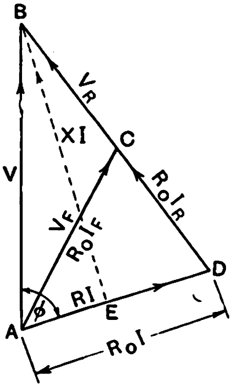


Fig. 5b.

Let R = Resistance of terminal load.

X = Reactance of terminal load.

$R_0 = \sqrt{\frac{L}{C}}$ = surge impedance of feeder.

V and I the amplitudes of voltage and current in the load.

V_x and I_x the resultant voltage and current at any point.

V_F and I_F amplitudes of voltage and current in the forward wave.

V_R and I_R ditto for reflected wave.

Then calling I and V positive when they are in the directions indicated in Fig. 5(*a*).

$$\frac{V_F}{I_F} = \frac{V_R}{I_R} = R_0.$$

also V_F and I_F are in phase, and V_R and I_R are in phase.

$\overline{V}$ = vector sum of V_F and V_R at the load $= \overline{V_F} + \overline{V_R}$

$\overline{I}$ = vector diff. of I_F and V_R at the load $= \overline{I_F} - \overline{I_R}$

In Fig. 5(*b*) *AC* represents $\overline{V_F}$ at the load
CB represents $\overline{V_R}$ at the load
so that *AB* represents $\overline{V}$

Similarly, if *BC* is produced to *D* making $DC = CB = V_R = R_0 I_R$. the $AD = AC - DC = R_0(\overline{I_F} - \overline{I_R}) = R_0\overline{I}$, *i.e.*, *AD* represents $R_0 I$ in magnitude and phase; angle $BAD = \phi$, the angle of lag of *I* behind *V*.

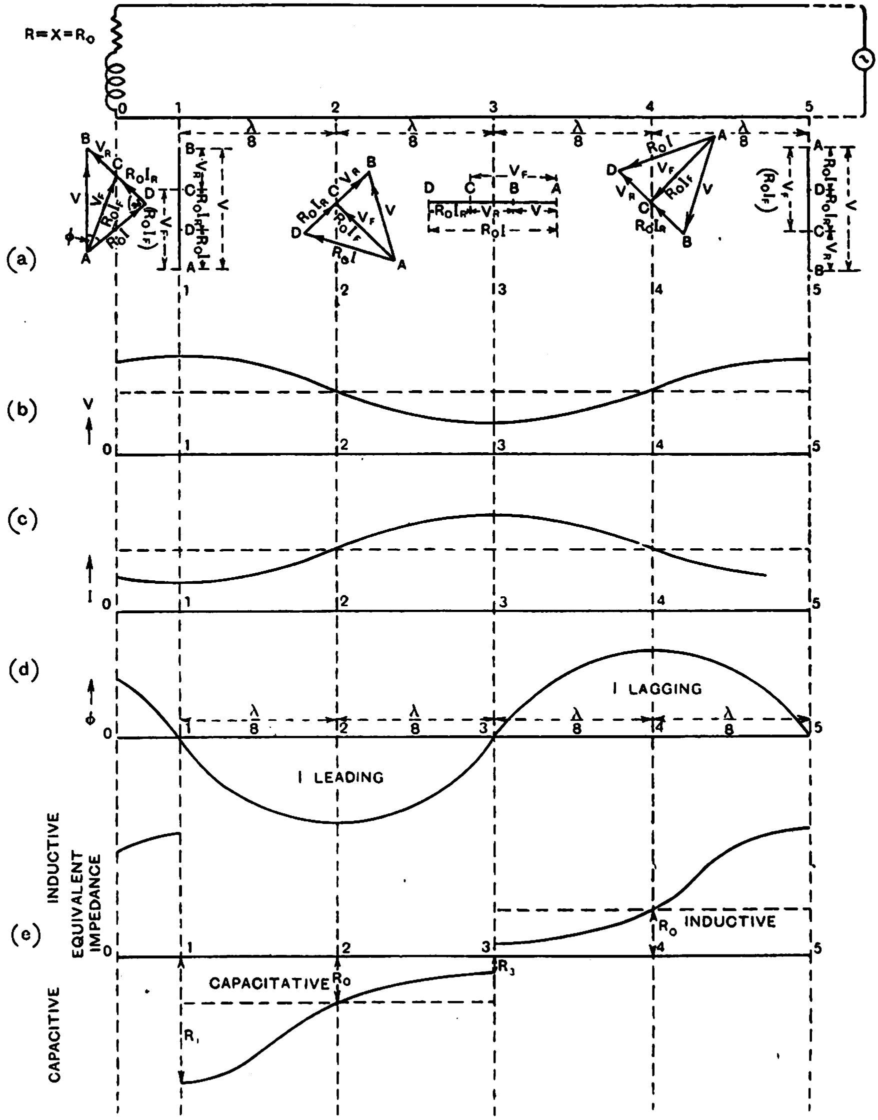


Fig. 6.

For the triangle of currents we know $V_F = R_0 . I_F$ and is in phase with I_F, so that *AC* represents I_F multiplied by R_0

If we are given the value of *R* and *X* at the load, to construct this Fig. 5(*b*) we assume a value for *I*. Then draw $AE = RI$ and

$EB = XI$. Then AB represents V and angle BAE = angle of lag of I behind V. Mark off along AE $AD = R_0 I$. Join B to D and A to C, the mid-point of BD. Then, as before stated, we have

AB represents V
AD " $R_0 I$
AC " V_F and $R_0 I_F$
CB " V_R
DC " $R_0 I_R$

This figure fully determines the conditions existing at the load.

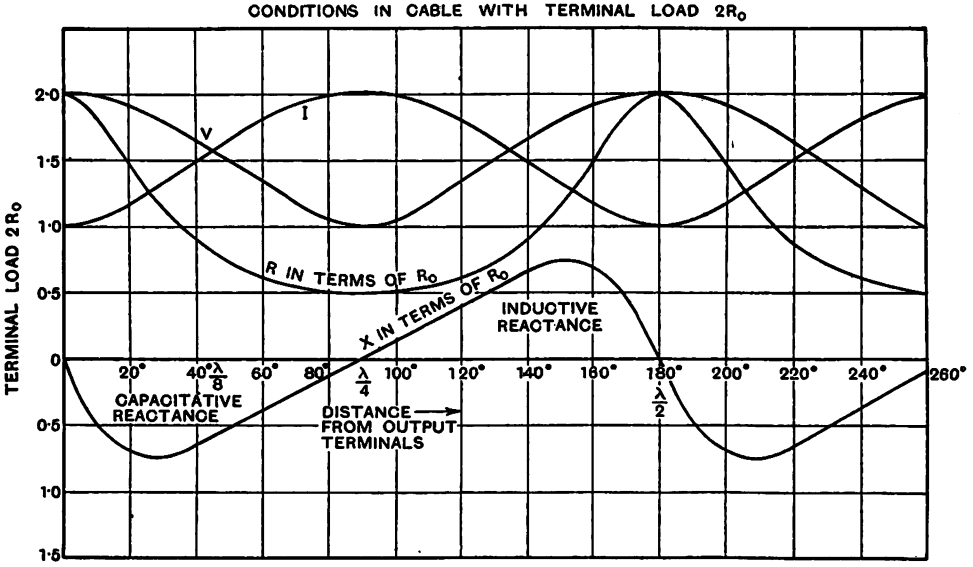


Fig. 7

To determine the conditions existing at a point in the feeder at a distance x from the load, we know the values of V_F and I_F existing at this point x will exist at the load $\frac{x}{\lambda}$ periods later (λ being the wavelength in the feeder). Hence, if we rotate AC in a counter-clockwise direction about C through an angle $\frac{2\pi x}{\lambda}$ radians $\left(i.e., \frac{360x}{\lambda} \text{ degrees}\right)$ we get V_F and I_F for the point x. Similarly, for V_R and I_R the conditions at x are those existing at the load $\frac{x}{\lambda}$ periods before; so that we must rotate BCD in a clockwise direction about C through $\frac{2\pi x}{\lambda}$ radians. Usually we only require the relations of V_x and I_x, and in this case it is easier to leave AC fixed and rotate BCD in a clockwise direction through $\frac{4\pi x}{\lambda}$ radians. BCD will then make a complete revolution for every $\frac{\lambda}{2}$ of the feeder. The resultant V_x and I_x for this point are given by AB and AD as before.

Up to the present we have assumed that the transmitter is so far away that only a single incident wave and a single reflected wave exist at the points considered. But, as before mentioned, we can imagine a feeder cut at x and the transmitter connected there, and if this supplies the same values of V_x and I_x that already existed there the same state of things will be maintained. The feeder and load will therefore behave as an impedance $= \frac{\overline{V}}{I}$ as regards the transmitter. This may be termed the equivalent impedance of the feeder and load at the point x, and will obviously vary with the distance x. We can also imagine the feeder cut at x, and the feeder beyond this point, plus the load, replaced by the equivalent impedance, and the original state of things would persist in the remaining portion of the feeder.

An example is worked out in Fig. 6 for an inductive load in which $R = X = R_0$, but the remarks below apply to any inductive load. At a distance less than $\frac{\lambda}{4}$ from the load AC and BCD come into line as shown in (*a*) 1. V and I are in phase, V (*i.e.*, AB) having its maximum value and I (*i.e.*, AD) its minimum value. Hence the equivalent impedance is a maximum, and is a pure resistance. At the point 2, $\frac{\lambda}{8}$ farther from the load AC is at right angles to BCD; and ϕ reaches its maximum negative value. $AD = AB$, *i.e.*, $V = R_0 I$. The equivalent impedance is equal to $\frac{V}{I} = R_0$ in magnitude but is capacitative. $\frac{\lambda}{8}$ farther back at 3, AC and BCD are in line again, but now V has its minimum value, and I its maximum value. Hence the equivalent impedance is a minimum, and is a pure resistance. If R_1 and R_3 are the values at 1 and 3, then

$$\sqrt{R_1 R_3} = R_0.$$

Thus in Fig. 6 for the resistance R_1 we have

$$R_1 = \frac{V}{I} = \frac{(AB)_1}{(AD)_1} R_0.$$

Whilst for the resistance R_3 at point 3 we have

$$R_3 = \frac{V}{I} = \frac{(AB)_3}{(AD)_3} R_0$$

$$\therefore \quad R_1 R_3 = \frac{(AB)_1}{(AD)_1} \cdot \frac{(AB)_3}{(AD)_3} R_0^2$$

but $(AB)_1 = (AD)_3$ and $(AD)_1 = (AB)_3$

$$\therefore \sqrt{R_1 R_3} = R_0.$$

$\frac{\lambda}{8}$ farther back at the point 4, AC and BCD are at right angles again; the equivalent impedance is equal to R_0, but this time it is inductive. At the point 5, $\frac{\lambda}{8}$ farther back still we get figure 5, which is similar to 1 except that all phases are reversed. Beyond this point the sequence will be repeated. Note that ϕ reaches equal positive and negative values, and the curve for ϕ is symmetrical about the maximum values.

The case for any other load can be similarly worked out, but the general sequence can be deduced from the present set of curves. Thus if the load is capacitative, it is equivalent to having the load situated in the section 1–3.

Pure Resistance Load.

If the load is a pure resistance it must be situated at 1 or 3, according as it is greater or less than R_0. If it is equal to kR_0, then at points along the feeder whose distances from the load are $\frac{1}{2}\lambda$, 1λ, $1\frac{1}{2}\lambda$, etc., the equivalent impedance is a pure resistance kR_0; whilst at points whose distances from the load are $\frac{1}{4}\lambda$, $\frac{3}{4}\lambda$, $\frac{5}{4}\lambda$, etc., it is a pure resistance $= \frac{1}{k} R_0$. This follows from

$$\sqrt{R_1 R_3} = R_0.$$

Fig. 7 shows the curves obtained for a terminal load of $2R_0$.

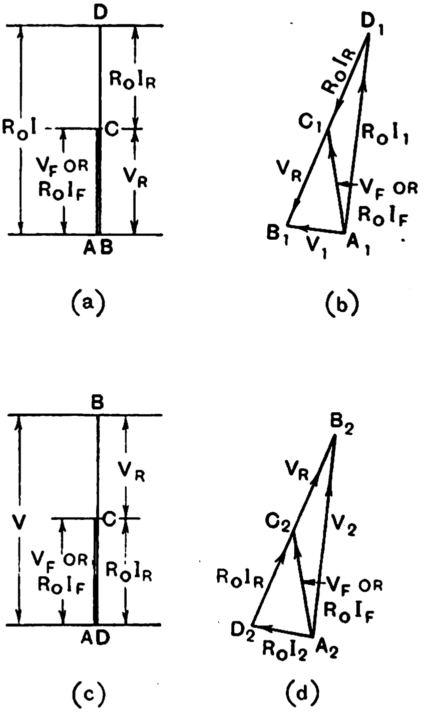


Fig. 8

Output Terminals on Short Circuit or on Open Circuit.

These special cases are of some interest. With the output terminals short circuited, the resultant voltage there must be zero, the voltage of the reflected wave being exactly equal and opposite to that of the forward wave. Hence the vector diagram for this is shown in Fig. 8(*a*). It is clear from this that the resultant current at the end is double that in either wave. Fig. 8(*b*) shows the vector diagram for some definite distance x from the output terminals. Since $AC = BC = CD$ the angle BAD between resultant current and resultant voltage will be a right angle whatever the value of x, *i.e.*, I and V are always in quadrature.

When the output terminals are open-circuited the resultant current must be zero, and the vector diagram takes the form of Fig. 8(*c*). As in the previous case, the reflected wave is equal in amplitude to the forward wave but is in opposite phase. The diagram of 8(*c*) is the same as 8(*a*) with the position of B and D interchanged. Hence at the same distance x from the output end the vector diagram becomes that of 8(*d*), which is a replica of 8(*b*) except that B and D are interchanged. Let the distance x be the distance of the input terminals, Z_1, the impedance of the feeder there for the case of short circuit, and Z_2 that for open circuit.

Then we have

$$Z_1 = \frac{V_1}{I_1} = \frac{A_1B_1}{A_1D_1} R_0 \text{ from } 8(b)$$

$$Z_2 = \frac{V_2}{I_2} = \frac{A_2B_2}{A_2D_2} R_0 \text{ from } 8(d)$$

$$\therefore \quad Z_1Z_2 = \frac{A_1B_1}{A_1D_1} \cdot \frac{A_2B_2}{A_2D_2} R_0^2$$

and since $A_1B_1 = A_2D_2$ and $A_1D_1 = A_2B_2$

$$\frac{A_1B_1}{A_1D_1} \cdot \frac{A_2B_2}{A_2D_2} = 1$$

$$\therefore \quad R_0 = \sqrt{Z_1 \cdot Z_2}$$

Hence, if we measure the impedance of a feeder both on open and short circuit, thus finding Z_1 and Z_2, we can find R_0, the surge impedance of the feeder.

Effect of Attenuation.

So far we have neglected the effect of attenuation in the feeder. If it is small but is given by e^{-ax} in a distance x, we can proceed thus: V_F and I_F are the forward wave amplitudes at the load. For the point distance x from the output end they must be multiplied by $\frac{1}{e^{-ax}} = e^{ax}$ and are therefore V_Fe^{ax} and I_Fe^{ax}. V_R and I_R will be attenuated in ratio e^{-ax}, becoming V_Re^{-ax} and I_Re^{-ax}. Otherwise the construction of the vector diagrams is unchanged.

Graphical Computation.

By M. H. Ashworth, Wh.Ex., B.Sc.

MANY problems arise in connection with wireless calculations that are, in the ordinary way, difficult or laborious to solve. An example of this latter class occurred in connection with the article "An Experimenter's Wireless Laboratory" in the April, 1926, issue of EXPERIMENTAL WIRELESS—namely, the calibration of a Moullin Voltmeter from D.C. characteristic of a valve. It is proposed to show how to solve this problem by graphics and mental arithmetic.

The method which is well known in some branches of engineering is a process of graphical integration. This particular problem could, perhaps, be more readily solved by means of a planimeter; but not many experimenters have such an instrument, and the application of ordinary rules to obtain areas are themselves laborious and often give inaccurate results.

It is first necessary to obtain the current-time graph showing the current flowing at any instant during the cycle. This is easily done if the grid-volts anode-current curve of the valve is arranged in the top left-hand corner of a sheet of squared paper, as shown in Fig. 1. The current axis produced to the right is a time axis for the alternating voltage, and on this axis are plotted the necessary sine curves. Three such curves are shown, namely: for one, two and three volts (peak values). The scale of volts must be the same as for the grid volts already plotted.

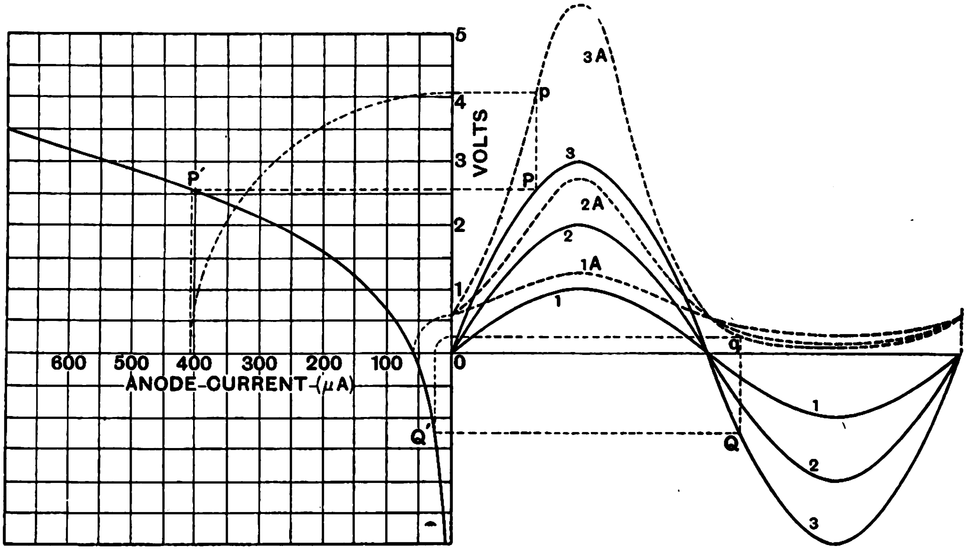


Fig. 1.

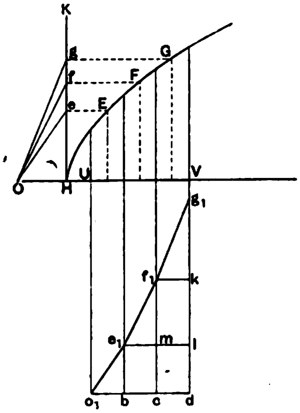


Fig. 2.

The current-time curve for any voltage curve can now be obtained with great ease and rapidity. From the two points *P* and *Q*, shown on the "three-volt" curve in Fig. 1, the method of obtaining the corresponding current-time curve is shown and is obvious. A horizontal line is drawn from *P* on the volt-time curve to meet the valve curve at *P'*; a perpendicular is dropped from *P'* on the current axis, and with *O* as centre and with this current as radius an arc is struck through a right angle to bring the current at right angles to the time axis. This point is then projected to meet the vertical line through *P* and we have obtained a point *p* on the current-time curve.

Three current-time curves are shown corresponding to the three voltage-time curves. The problem is now to determine the area between each of these curves and the time axis so that the mean value of the current can be found. This could be done rapidly with a planimeter, as already pointed out, but Fig. 2 illustrates a graphical method.

In this case, let it be desired to find the area between the curve *EFG* and the axis (between points *U* and *V* on the latter). Divide *UV* into any number of parts (equal or unequal) and draw the mid-ordinate in each of these intervals as shown by the dotted lines. From the points where these mid-ordinates cut the curve draw horizontal lines *Ee*, *Ff*, etc., to cut a vertical line *HK*. Make *HO* (along the horizontal axis produced to the left) equal to one inch and join *Oe*, *Of*, etc.

Starting at any point on the vertical through *U*, draw $o_1\ e_1$ parallel to *Oe* across the space or interval *E*; likewise draw $e_1\ f_1$ and $f_1\ g_1$ parallel to *Of* and *Og* respectively across the spaces *F* and *G*, as shown.

Then be_1 measured in inches gives the area in square inches of the portion of the curve under *E* in interval 1; mf_1 in the same way gives the area under *F* and similarly for any remaining intervals. The whole area is dg_1.

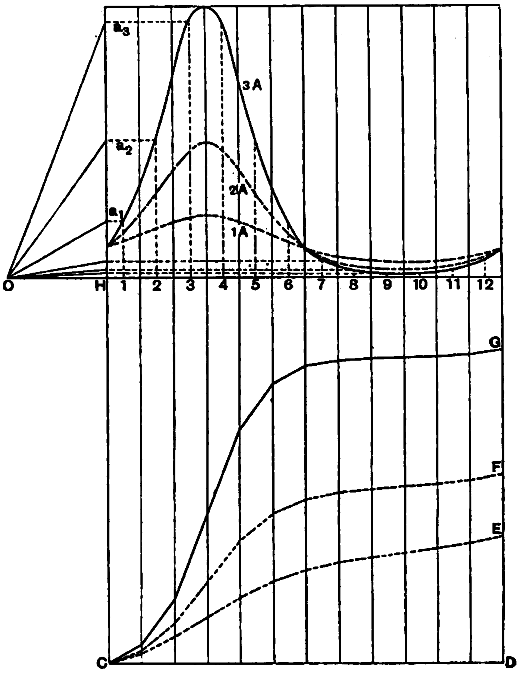


FIG. 3.

Consider the triangles *OHe* and o_1be_1. They are similar, therefore

$$\frac{OH}{He}=\frac{o_1b}{be_1}\text{ or } o_1b\times He=OH\times be_1,$$

but $o_1b\times He$=area under E;

therefore, $OH\times be_1$=area under E,

and since *OH* equals one inch, be_1 in inches gives numerically the area under *E* in square inches. If *OH* had been made 2 inches instead of 1 inch, then $2\times be_1$ would give the required area.

This method is applied in Fig. 3 to our current-time curves. In order to avoid complications these current curves have been redrawn on a new diagram. In practice there is no need to do this, the lower part of Fig. 3 being drawn directly below the right hand portion of Fig. 1. One result and the necessary construction is shown in full for a current curve corresponding to 3 volts peak value. The results for the other two current curves are also shown dotted, but to avoid complications in illustrating this example the working is not shown for these two curves. The pole distance chosen is 2 inches and on measuring the ordinates *DG*, *DF* and *DE* and multiplying each by *OH* (=2 inches) we obtain the following areas:—

12.76 sq. inches, 7.70 sq. inches and 5.20 sq. inches respectively. Thus, since the period of one cycle is represented by 8 inches, the mean heights of the current curves are:—

1.59, 0.963 and 0.65 inches respectively, giving mean anode currents of:—

159, 96.3 and 65 micro-amps. respectively. Thus, since the current for zero volts is 57 μA, the increase of anode current is:—

102, 39.3 and 8μA respectively (corresponding to cycles with peak voltages of 3, 2 and 1 volts).

Other curves may be drawn and more values obtained, and so the calibration curve drawn. A fair idea can, however, be obtained from the four values obtained, namely:—

Volts	..	0	1	2	3
Current	..	57	65	96	159

(The valve used is a Radio Micro with 44 volts on the anode, and 3.5 on the filament. A lower valve of about 33 volts on the anode would give equally good results and there would also be a lower current at zero volts. The bias is 3½ volts.)

It may possibly be thought by some that the method is not sufficiently accurate. A few examples will suffice to satisfy on this point. The area under each of the curves 1*A*, 2*A* and 3*A* was carefully measured by means of a planimeter, the mean of four readings being taken. These gave:—

5.21, 7.85 and 12.79 sq. inches.

On comparing these with our values, *i.e.*, with

5.20, 7.70 and 12.76 sq. inches,

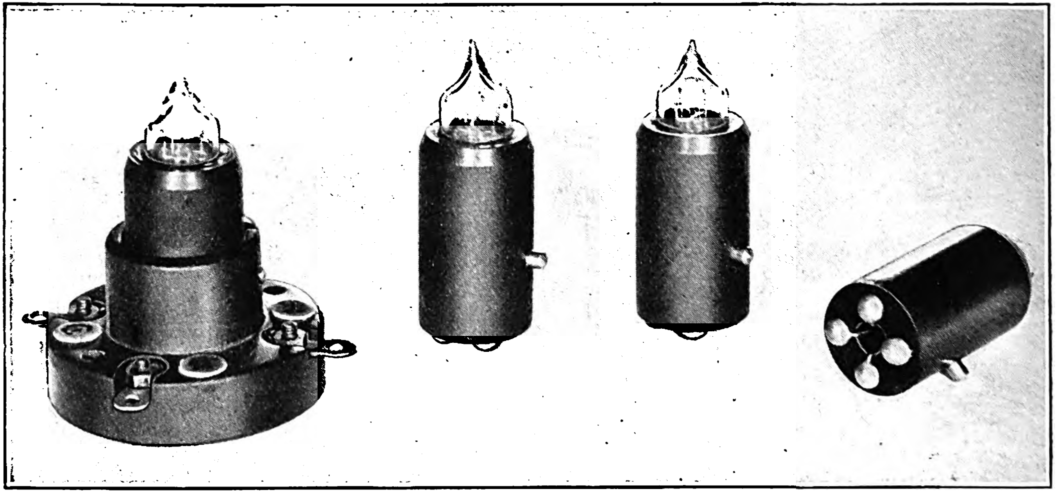
we see that we can rely on our results to about 1 per cent. (The middle result is abnormally far out.)

The great value of the method becomes more apparent when it is necessary to obtain successive integrations of a curve. Even with four such integrations an error exceeding 2 per cent. rarely occurs, and more often than not the error is not more than 1 per cent. The method is rapid and two successive integrations over twelve intervals with the numerical results required can be obtained without fatigue in thirty minutes.

[Note.—*MS. received by the Editors April,* 1926.]

Spot-welded Thermojunctions.

MESSRS. COLLIER & STEPHENSON, 102, High Street, Hornsey, London, N.8, have recently produced a range of vacuum thermocouples possessing several advantages over the ordinary soldered junction. The couple, which consists of iron and constantan, is spot-welded to the heater wire, which is of nichrome, platinum or constantan, depending on the current range of the junction.



A new range of thermocouples, by Messrs Collier & Stephenson, with spot-welded junctions ; they fit into " Wecovalve " bases.

With a spot-welded junction there is less risk of the couple wires including a short length of the heater, as frequently happens in the case of a soldered junction. There is thus an almost complete absence of the spurious E.M.F. in the couple circuit due to the voltage drop along the heater wire which is the cause, when calibrating with D.C., of the difference in scale reading sometimes experienced on reversing the current.

The spot-welded junction is also less susceptible to damage from overloading. Near the maximum current for which the junction has been designed, the temperature of the heater wire may approach the melting point of the solder with disastrous results to the calibration if not permanent injury to the couple.

The vacuum thermocouples under review are mounted in ebonite bases which fit into standard " Wecovalve " holders. Four ranges are available and specimens submitted had the following characteristics :—

Couple No.	Range.	Heater Resistance.	Output.
859	10 mA.	52.0 ohms	3 mV. across 3 ohms for 9.2 mA.
860	25 mA.	29.0 „	6 mV. „ 3 „ „ 23.5 mA.
861	50 mA.	11.0 „	6 mA. „ 3 „ „ 32.5 mA.
862	1 amp.	0.1 „	6 mA. „ 3 „ „ 0.92 amp.

The junctions will take a 50 per cent. overload without damage or alteration of calibration. The couple resistance is of the order of 3 ohms in each case, and the vacuum is reduced to 0.00001 mm. Hg.

On Banks of Paralleled Valves Feeding Resistive Loads Without Distorting the Wave Form.

By W. Baggally.

THE following paper deals with the problems which arise in the work of designing a bank of valves for supplying power to loud speakers, etc., in the form of undistorted speech and music, the treatment being confined to the case of a non-reactive load.

There are four conditions which must be fulfilled by a bank supplying power without distorting the wave form; they are:—

(1) The anode current must not rise above the top of the straight part of the characteristic curve.

(2) The anode current must not fall below the bottom end of the straight part of the characteristic curve.

(3) The grids must never receive a positive charge.

(4) The power dissipated at the anodes must not be greater than that for which the valves were designed.

The circuit to be considered is that shown in the diagram, Fig. 1, and usually known as choke feed; it is quite general and applies equally well to transformer or direct fed arrangements.

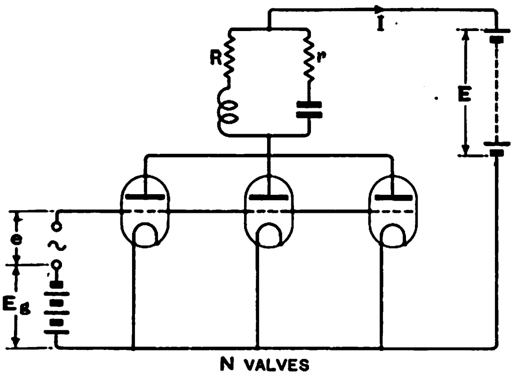


Fig. 1.

The inductance and capacity are both considered infinitely great.

In the case of transformer or direct feed, R will be the static resistance and r the dynamic resistance of the transformer primary or loud speaker winding as the case might be.

The symbols used in the analysis are as follows:

a = anode current at bottom end of linear part of characteristic.
b = anode current at top end of linear part of characteristic.
D = allowable anode dissipation in each valve.
E = supply voltage.
E_a = steady anode voltage.
E_g = steady grid voltage.
e = maximum value of A.C. grid voltage.
$\bar{E}_a$ = total instantaneous anode voltage.
$\bar{E}_g$ = total instantaneous grid voltage.
I = D.C. feed current to bank.
i = current through load (A.C.).
$\bar{I}$ = total instantaneous current to bank.
$\bar{I}_a$ = total instantaneous anode current to each valve.
N = number of valves in parallel.
p = A.C. power in load.
R = resistance of feed choke.
r = resistance of load.
R_a = slope resistance of each valve.
m = voltage factor of each valve.
v = internal E.M.F. of valve (see appendix).
P = power supplied to the whole system.
P_R = power dissipated in R.
P_v = power dissipated in the bank.

The conditions for distortionless working can now be written as follows:—

(1) $\bar{I} \ngtr Nb.$
(2) $\bar{I} \nless Na.$
(3) $E_g + e \ngtr 0.$
(4) $P_v \ngtr ND.$

Now we have from energy considerations:

$$P = P_R + P_v + p \quad \ldots \quad (1)$$

also $$P = \frac{1}{r}\int_0^r E(I + i \sin \omega t)dt = EI \quad \ldots \quad (2)$$

and $$p = \frac{i^2r}{2} \quad \cdots \quad (3)$$

and $$P_R = I^2R \quad \cdots \quad (4)$$

therefore $$P_r = EI - I^2R - \frac{i^2r}{2} < EI - I^2R \quad (5)$$

It follows from this that the valves are more heavily loaded during periods of silence than when handling speech current, therefore it is necessary to design the bank so that it is safely loaded when quiescent, then *a fortiori* it will be safely loaded when handling A.C. power.

If, therefore, $EI - I^2R \leqq ND$ .. (6)

condition 4 above will be satisfied.

For the linear part of the characteristic, we have

$$\bar{I}_a = \frac{m\bar{E}_g + \bar{E}_a + v}{R_a} \quad \cdots \quad (7)$$

Referring to the diagram, the A.C. voltage across the condenser and r is $ir \sin \omega t$, while the D.C. voltage across the condenser and r is IR.

It follows from this that

$$\bar{E}_a = E - IR - ir \sin \omega t \quad \cdots \quad (8)$$

We also have $\bar{E}_g = E_g + e \sin \omega t$ .. (9)

and $$\bar{I}_a = \frac{I}{N} + \frac{i}{N} \sin \omega t \quad \cdots \quad (10)$$

so that from (7), (8), (9) and (10) we obtain

$$\frac{I}{N} + \frac{i}{N} \sin \omega t = \frac{mE_g + me \sin \omega t + E - IR - ir \sin \omega t + v}{R_a} \quad (11)$$

By equating coefficients of unity and sin ωt we obtain

$$\frac{I}{N} = \frac{mE_g + E + v - IR}{R_a} \quad \cdots \quad (12)$$

$$\frac{i}{N} = \frac{me - ir}{R_a} \quad \cdots \quad (13)$$

which on transposition become

$$I = \frac{mE_g + E + v}{\frac{R_a}{N} + R} \quad \cdots \quad (14)$$

$$i = \frac{me}{\frac{R_a}{N} + r} \quad \cdots \quad (15)$$

so that equation (6) becomes by substitution of (14)

$$E \frac{mE_g + E + v}{\frac{R_a}{N} + R} - R \left[\frac{mE_g + E + v}{\frac{R_a}{N} + R} \right]^2 \leqq ND \quad (16)$$

Now $$\bar{I}_{\text{max.}} = I + i \quad \cdots \quad (17)$$

$$\bar{I}_{\text{min.}} = I - i \quad \cdots \quad (18)$$

from which it follows that conditions 1, 2, 3 and 4 may be expressed as under:

1 $$\frac{mE_g + E + v}{\frac{R_a}{N} + R} + \frac{me}{\frac{R_a}{N} + r} \leqq Nb \quad \cdots \quad (19)$$

2 $$\frac{mE_g + E + v}{\frac{R_a}{N} + R} - \frac{me}{\frac{R_a}{N} + r} \geqq Na \quad \cdots \quad (20)$$

3 $$E_g + e \leqq 0 \quad \cdots \quad (21)$$

4 $$E \frac{mE_g + E + v}{\frac{R_a}{N} + R} - R \left[\frac{mE_g + E + v}{\frac{R_a}{N} + R} \right]^2 \leqq ND \quad \cdots \quad (22)$$

Now suppose that we start with such a large negative grid bias that the anode current is reduced to the value a, and that as the grid is made less negative, e is increased at the same rate so as always to cause the lower peaks of current to descend to the point a, then for a given value of E_g it will not be possible to increase e further without introducing distortion.

One of three things may occur to stop the extension of grid swing, the one supervening first being the limiting factor.

Either:

(*a*) The upper peaks of anode current reach b, in which case equations (20) and (19) hold simultaneously.

(*b*) The steady anode current reaches such a value that the anodes are dissipating the maximum permissible power, in which case equations (20) and (22) hold simultaneously.

(*c*) The upper peaks of grid potential reach zero, in which case equations (20) and (21) hold simultaneously.

Case a:

By adding (19) and (20) and rearranging terms we have

$$E_g = \frac{\frac{1}{2}(b+a)(R_a+NR)-E-v}{m} \quad . \quad (23)$$

by subtracting and transposing

$$e = \frac{(b-a)(R_a+Nr)}{2m} \quad .. \quad (24)$$

and from (3), (15) and (24)

$$p = \frac{m^2 r N^2}{2(R_a+Nr)^2} \cdot \frac{(b-a)^2(R_a+Nr)^2}{4m^2}$$

$$= \frac{N^2 r(b-a)^2}{8} \quad .. \quad (25)$$

Case b:

By putting $I = \dfrac{mE_g + E + v}{\frac{R_a}{N} + R}$ in (22) and solving we have

$$I = \frac{E - \sqrt{E^2 - 4RDN}}{2R} \quad .. \quad (26)$$

which gives

$$E_a = -\frac{E+v}{m} + \frac{R_a+NR}{2mNR}(E - \sqrt{E^2 - 4RDN} \quad . \quad (27)$$

Equation (20) may be written

$$\frac{me}{\frac{R_a}{N}+r} + Na = I \quad .. \quad .. \quad (28)$$

and this, together with (26), when combined and transposed, gives

$$e = \frac{\frac{R_a}{N}+r}{m}\left[\frac{E-\sqrt{E^2-4RDN}}{2R} - Na\right] \quad . \quad (29)$$

and on combining this with (3) and (15) we obtain

$$p = \frac{r}{2}\left[\frac{E-\sqrt{E^2-4RDN}}{2R} - Na\right]^2 \quad . \quad (30)$$

Case c:

Substituting (21) in (20),

$$\frac{E+v-me}{\frac{R_a}{N}+R} - \frac{me}{\frac{R_a}{N}+r} = Na \quad .. \quad (31)$$

which on transposition gives

$$e = \frac{1}{m} \cdot \frac{R_a+Nr}{2R_a+NR+Nr} (E+v-a\{R_a+NR\}) \quad (32)$$

This last equation together with (21) gives

$$E_g = -\frac{1}{m} \cdot \frac{R_a+Nr}{2R_a+NR+Nr} (E+v-a\{R_a+NR\}) \quad .. \quad (33)$$

Combining (32) with (3) and (15) gives

$$p = \frac{rN^2(E+v-a\{R_a+NR\})^2}{2(2R_a+NR+Nr)^2} \quad .. \quad (34)$$

Summarising, we have

$$p = \frac{N^2 r(b-a)^2}{8} = A \text{ for condition } a.$$

$$p = \frac{r}{2}\left[\frac{E-\sqrt{E^2-4RDN}}{2R} - Na\right]^2 = B$$

for condition b.

$$p = \frac{rN^2(E+v-a\{R_a+NR\})^2}{2(2R_a+NR+Nr)^2} = C$$

for condition c.

The value of r which, other conditions remaining constant, gives the maximum value of p will now be determined.

First it is to be noted that if condition c is the limiting factor, p will be a maximum when $r = 2\frac{R_a}{N} + R$, which is easily seen to be the case by differentiating C to r and equating to zero.

Again, the graphs of A and B plotted against r are straight lines passing through the origin, so that if we plot A, B and C on the same diagram, it presents some such appearance as Fig. 2, the points X, Y and Z being the intersection of A and C, B and C, and the maximum point of C, respectively.

Whichever one of these three points has the greatest abscissa, by its ordinate represents the maximum power obtainable, and by its abscissa, the value of r necessary to obtain this power.

This is evident if we remember that that condition (A, B or C) is the governing one which puts the greatest restriction on p. Then, referring to Fig. 2, it is seen that as we increase r, p increases until it reaches X, Y or Z, whichever is furthest to the right, *i.e.*, whichever has the greatest abscissa.

If we call the abscissæ of X, Y, and Z, r_1, r_2 and r_3 respectively, by equating A and C and performing some reduction and simplification we obtain

$$r_1 = \frac{2(E + v - a\{R_e + NR\})}{N(b - a)} - \left(2\frac{R_e}{N} + R\right) \quad .. \ (35)$$

Similarly, by equating B and C and simplifying, we get

$$r_2 = \frac{2R(E + v - a\{R_e + NR\})}{E - \sqrt{E^2 - 4RDN} - 2NaR} - \left(2\frac{R_e}{N} + R\right) \quad .. \ (36)$$

while for the point Z we have

$$r_3 = 2\left(\frac{R_e}{N} + R\right) .. \quad .. \ (37)$$

so that the optimum value of r is obtained

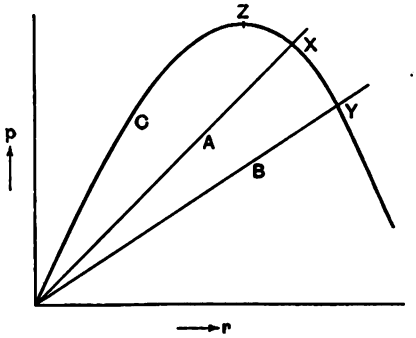


Fig. 2.

by working out r_1, r_2 and r_3 and taking whichever is the greatest.

Since X, Y and Z all lie on the curve C, it follows that p and E_g will always be given by (34) and (33) respectively, irrespective of whether r is obtained from (35), (36) or (37).

If, on the other hand, r has some arbitrarily assigned value other than the optimum, it will be necessary to determine A, B and C, taking the one which is least as the value of p, afterwards calculating E_g from the appropriate formula corresponding to A, B or C.

In order to get a rough basis for design, it is convenient to neglect a, v and R; this very greatly simplifies the above equations and also enables us to obtain an approximate expression for N in terms of p, E and the constants of the valves.

Expanding by the binomial theorem we have

$$\frac{2R}{E-\sqrt{E^2-4RDN}} = \frac{\frac{2R}{E}}{\frac{kR}{2}+\frac{k^2R^2}{8}+\frac{k^3R^3}{16}+\text{etc.}}$$

$$\text{where} \qquad k = \frac{4DN}{E^2} \quad .. \quad .. \ (38)$$

therefore

$$\mathop{\mathrm{Lt}}_{R\to 0} \frac{2R}{E - \sqrt{E^2 - 4RDN}} = \frac{\frac{2R}{E}}{\frac{kR}{2}} = \frac{4}{kE} = \frac{E}{DN} \ . \ (39)$$

Putting $a = 0$, $v = 0$ and $R = 0$ in (33), (34), (35), (36) and (37) we get (applying (39) where necessary):

$$E_g = -\frac{E}{m} \cdot \frac{R_e + Nr}{2R_e + Nr} \quad .. \ (40)$$

$$p = \frac{rN^2E^2}{2(2R_e + Nr)^2} \quad .. \quad .. \ (41)$$

$$r_1 = \frac{2}{N}\left(\frac{E}{b} - R_e\right) \quad .. \quad .. \ (42)$$

$$r_2 = \frac{1}{N}\left(\frac{E^2}{D} - 2R_e\right) \quad .. \quad .. \ (43)$$

$$r_3 = \frac{2R_e}{N} \quad .. \quad .. \quad .. \ (44)$$

Now if we substitute r_1, r_2 and r_3 in (41), calling the values of p so obtained p_1, p_2 and p_3 respectively, we have:

$$p_1 = N\frac{b}{4}(E - bR_e) \quad .. \ (45)$$

$$p_2 = ND\left(\tfrac{1}{2} - \frac{DR_e}{E^2}\right) \quad .. \ (46)$$

$$p_3 = N\frac{E^2}{16R_e} .. \quad .. \quad .. \ (47)$$

By transposition of these last three we get

$$N = \frac{4p_1}{b(E - bR_e)} \quad .. \quad .. \ (48)$$

$$N = \frac{p_2}{D\left(\frac{1}{2} - \frac{DR_a}{E^2}\right)} \quad \cdots \quad \cdots (49)$$

$$N = \frac{16p_3R_a}{E^2} \quad \cdots \quad \cdots (50)$$

Since p_1, p_2 and p_3 all increase with increase of N, and the least of these is the power obtainable, it follows that if we make p_1, p_2 and p_3 all equal to p by putting different values of N in the three formulæ, the largest of these three values of N will make the power available equal to p, since it makes either p_1 or p_2 or p_3 equal to p, and at the same time makes the other two larger than p.

The approximate determination of N when r has an arbitrarily assigned value other than the optimum may be accomplished in a similar manner as follows:

Putting $a = 0$, $v = 0$ and $R = 0$ in (25), (30) and (34) gives

$$p = N^2\frac{rb^2}{8} \quad \cdots \quad \cdots \quad \cdots (51)$$

$$p = N^2\frac{rD^2}{2E^2} \quad \cdots \quad \cdots \quad \cdots (52)$$

$$p = N^2\frac{rE^2}{2(2R_a + Nr)} \quad \cdots (53)$$

which all increase with increase of N.

Transposing them we have

$$N = \frac{2}{b}\sqrt{\frac{2p}{r}} \quad \cdots \quad \cdots (54)$$

$$N = \frac{E}{D}\sqrt{\frac{2p}{r}} \quad \cdots \quad \cdots (55)$$

$$N = \frac{2R_a\sqrt{\frac{2p}{r}}}{E - \sqrt{2pr}} \quad \cdots \quad \cdots (56)$$

and for reasons similar to the above, we select the largest of these three values of N.

The above results may be conveniently embodied in four Rules, which should suffice for the solution of most numerical problems on valve banks.

In a few special cases it may be necessary to rearrange or modify some of the equations given above so as to fit a particular problem.

Rule 1. To find the power available, the grid bias, and the amplitude of the applied alternating grid potential, given the valve constants, and R, r, E and N.

Find p from A_1, B_1 and C_1, and which ever is the least is the power, the other two members of the group giving the grid bias and amplitude of grid swing.

$$p = \frac{N^2r(b-a)^2}{8} \quad \cdots \quad \cdots \quad \cdots \quad A_1$$

$$E_g = \frac{-1}{m}\left(E + v - \tfrac{1}{2}\{b + a\}\{R_a + NR\}\right) \quad . \quad A_2$$

$$e = \frac{(b-a)(R_a + Nr)}{2m} \quad \cdots \quad \cdots \quad \cdots \quad A_3$$

$$p = \frac{r}{2}\left[\frac{E - \sqrt{E^2 - 4RDN}}{2R} - Na\right]^2$$

$$= \frac{rN^2}{2}\left[\frac{D}{E} - a\right]^2 \text{ if } R = 0 \quad \cdots \quad B_1$$

$$E_g = \frac{-1}{m}\left(E + v - \frac{R_a + NR}{2NR}\{E - \sqrt{E^2 - 4RDN}\}\right)$$

$$= \frac{-1}{m}\left[E + v - \frac{DR_a}{E}\right] \text{ if } R = 0 \quad \cdots \quad B_2$$

$$e = \frac{R_a + Nr}{mN}\left[\frac{E - \sqrt{E^2 - 4RDN}}{2R} - Na\right]$$

$$= \frac{R_a + Nr}{m}\left(\frac{D}{E} - a\right) \text{ if } R = 0 \quad \cdots \quad B_3$$

$$p = \frac{rN^2\,(E + v - a\{R_a + NR\})^2}{2\,(2R_a + NR + Nr)^2} \quad \cdots \quad C_1$$

$$E_g = \frac{-1}{m} \cdot \frac{R_a + Nr}{2R_a + NR + Nr}(E + v - a\{R_a + NR\}) \quad \cdots \quad C_2$$

$$e = \frac{1}{m} \cdot \frac{R_a + Nr}{2R_a + NR + Nr}(E + v - a\{R_a + NR\}) \quad \cdots \quad C_3$$

Example. Find the power delivered to a 2,000 ohm load by a bank of 10 LS5a valves fed from a 400-volt supply through a choke whose resistance is 200 ohms. Find, also, the grid bias and amplitude of grid swing.

Take the valve constants as: $b = 0.1$ amp.; $a = 0.005$ amp.; $v = 4$ volts negative; $m = 2.5$; $R_a = 2{,}750$ ohms; $D = 10$ watts.

A_1 gives

$$p = \frac{10^2 \times 2000 \times (.1 - .005)^2}{8} = 225 \text{ watts.}$$

B_1 gives

$$p=\frac{2000}{2}\left[\frac{400-\sqrt{400^2-4\times200\times10\times10}}{2\times200}-10\times.005\right]^2=60\text{ watts.}$$

C_1 gives

$$p=\frac{2000\times10^2(400-4-.005\{2750+10\times200\})^2}{2(2\times2750+10\times200+10\times2000)^2}=18\text{ watts}\cdot$$

The least of these is 18 watts, so that this is the power, and since this is given by C_1 we use C_2 and C_3 to determine the grid bias and amplitude of grid swing.

C_2 gives

$$E_g=\frac{-1}{2.5}\cdot\frac{2750+10\times200}{2\times2750+10\times200+10\times2000}[400-4-.005(2750+10\times200)]=-123\text{ volts.}$$

C_3 gives $e=-E_g=123$ volts.

Rule 2. To find the value of r necessary to make the power delivered by a given bank a maximum, and to find the value of this power, also the grid bias, and the amplitude of the alternating grid potential, given the valve constants, and R, E and N.

Find r from D_1, D_2 and D_3, then the greatest of these is the value of r which will make p a maximum.

Substitute this value of r in equations E and F to obtain p, E_g and e.

$$r=\frac{2(E+v-a\{R_a+NR\})}{N(b-a)}-\left(2\frac{R_a}{N}+R\right)\quad\ldots\quad D_1$$

$$r=\frac{2R(E+v-a\{R_a+NR\})}{E-\sqrt{E^2-4RDN}-2NaR}-\left(2\frac{R_a}{N}+R\right)$$

$$=\frac{E}{N(D-aE)}(E+v-aR_a)-2\frac{R_a}{N}\text{ if }R=0\ldots D_2$$

$$r=2\frac{R_a}{N}+R\quad\ldots\quad\ldots\quad\ldots\quad\ldots\quad D_3$$

$$p=\frac{rN^2(E+v-a\{R_a+NR\})^2}{2(2R_a+NR+Nr)^2}\quad\ldots\quad E$$

$$-e=E_g=\frac{-1}{m}\,\frac{R_a+Nr}{2R_a+NR+Nr}(E+v-a\{R_a+NR\})\quad\ldots\quad F$$

Example. Find the value of r for maximum power in the last example, also find this power, the grid bias and the amplitude of grid swing.

D_1 gives

$$\frac{2(400-4-.005\{2750+10\times200\})}{10(.1-.005)}-\left(\frac{2\times2750}{10}+200\right)=33.7\text{ ohms.}$$

D_2 gives

$$\frac{2\times200(400-4-.005\{2750+10\times200\})}{400-\sqrt{400^2-4\times200\times10\times10}-2\times10\times200+.005}-\left(\frac{2\times2750}{10}+200\right)=769.4\text{ ohms.}$$

D_3 gives $\dfrac{2\times2750}{10}+200=750$ ohms.

The greatest of these is 769.4 ohms, say 770, so that this is the value of r required to make p a maximum.

Substituting it in equations E and F, we obtain p, E_g and e.

E gives

$$p=\frac{770\times10^2(400-4-.005\{2750+10\times200\})^2}{2(2\times2750+10\times200+10\times770)^2}=23\text{ watts.}$$

F gives

$$-e=E_g=\frac{-1}{2.5}\cdot\frac{2750+10\times770}{2\times2750+10\times200+10\times770}\Big(400-4-.005(2750+10\times200)\Big)=-125\text{ volts.}$$

Rule 3. To find the approximate number of valves in parallel required to supply a given power to a given load, having given also the valve constants and the supply voltage.

Determine N from equations G_1, G_2 and G_3, then the largest of these is the number of valves required.

$$N=\frac{2}{b}\sqrt{\frac{2p}{r}}\quad\ldots\quad\ldots\quad\ldots\quad\ldots\quad G_1$$

$$N=\frac{E}{D}\sqrt{\frac{2p}{r}}\quad\ldots\quad\ldots\quad\ldots\quad\ldots\quad G_2$$

$$N=\frac{2R_a\sqrt{\dfrac{2p}{r}}}{E-\sqrt{2pr}}\quad\ldots\quad\ldots\quad\ldots\quad G_3$$

Example. It is required to drive a

phonic motor of dynamic resistance 1,000 ohms at the frequency to be used. The machine consumes 20 watts under the conditions of operation and the supply voltage available is 400. How many LS5a valves will be required?

$$G_1 \text{ gives } N = \frac{2}{.1}\sqrt{\frac{2 \times 20}{1000}} = 4$$

$$G_2 \text{ gives } N = \frac{400}{10}\sqrt{\frac{2 \times 20}{1000}} = 8$$

$$G_3 \text{ gives } N = \frac{2 \times 2750 \sqrt{\frac{2 \times 20}{1000}}}{400 - \sqrt{2 \times 20 \times 1000}} = 5.5$$

We select the largest of these; therefore we require 8 valves.

Rule 4. To find the approximate number of valves in parallel required to supply a given power when the load is so adjusted as to make the number of valves a minimum.

Determine N from equations H_1, H_2 and H_3, then the largest of these is the number of valves required.

$$N = \frac{4p}{b(E - bR_a)} \quad \cdots \quad \cdots \quad \cdots \quad H_1$$

$$N = \frac{p}{D\left(\frac{1}{2} - \frac{DR_a}{E^2}\right)}. \quad \cdots \quad \cdots \quad \cdots \quad H_2$$

$$N = \frac{16pR_a}{E^2} \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad H_3$$

Example. Suppose that in the last example we decide to economise valves by introducing a transformer between the bank and the motor.

Neglecting transformer losses, find the number of valves and the ratio of the transformer.

$$H_1 \text{ gives } \frac{4 \times 20}{.1(400 - .1 \times 2750)} = 6.4$$

$$H_2 \text{ gives } \frac{20}{10\left(\frac{1}{2} - \frac{10 \times 2750)}{400^2}\right.} = 6.1$$

$$H_3 \text{ gives } \frac{16 \times 20 \times 2750}{400^2} = 5.5$$

The greatest of these is 6.4, therefore we require 7 valves.

To determine r we turn back to Rule 2, and on substituting in equations D_1, D_2 and D_3,

D_1 gives

$$r = \frac{2(400-4-.005\times 2750)}{7(.1-.005)} - \frac{2\times 2750}{7} = 363 \text{ ohms.}$$

D_2 gives

$$r = \frac{400}{7(10-400\times .005)}(400-4-.005\times 2750) - \frac{2\times 2750}{7} = 1{,}928 \text{ ohms.}$$

$$D_3 \text{ gives } r = \frac{2 \times 2750}{7} = 786 \text{ ohms.}$$

Therefore the best value of r is about 2,000 ohms; this means that 1,000 ohms in the secondary is to be equivalent to 2,000 ohms in the primary, thus we require a step down transformer with ratio $1 : \sqrt{2} = 1 : 1.41$.

Since the error in N due to neglecting a, v, and R in Rules 3 and 4 is always negative, and also any want of adjustment in the grid bias, etc., will always decrease p and never increase it, it is often advisable to allow one more valve than the number given by these formulæ so as not to run things too fine; for instance, in the last two examples, it would probably be advisable to use eight valves with the transformer or nine without.

If the value of the feed current is required, it may always be found from equation (14), having first determined E_g in the course of working out the design by the above rules.

Appendix. v may readily be derived from the grid-anode characteristic curve and the slope resistance as follows:

Let E_a be the anode voltage at which the curve was plotted; then if I_a is the anode current corresponding to zero grid volts, and if R_a is the slope resistance, it is easily seen that $v = I_a R_a - E_a$. It usually amounts to a few volts negative.

Damping Due to Grid Current in the Case of a Valve Oscillator.

By M. Reed, B.Sc., A.C.G.I., D.I.C.

In the following article a simple "tuned anode" oscillator is considered, and it is shown how to calculate the damping introduced into the oscillatory circuit owing to grid current.

Consider the oscillator shown in Fig. 1, where L = inductance of the anode coil,
and M = mutual induction between the anode and grid coils.

Then if V_t = oscillatory voltage across L at any instant
and I_t = the corresponding current

we have that $V_t = \omega L I_t$

where $\omega = 2\pi \times$ frequency of the oscillation. The resistance of L is neglected.

The E.M.F. induced in the grid coil

$$= V_g = \omega M I_t = \omega M \cdot \frac{V_t}{\omega L} = \frac{M}{L} \cdot V_t.$$

Now the condition for the maintenance of oscillations in the anode circuit demands that the anode and grid voltages should be 180 degrees out of phase. Therefore, if we assume that the oscillatory voltage varies sinusoidally, then the anode and grid voltages will be related in the manner indicated by Fig. 2.

If the value of the H.T. voltage is E, then at the instant under consideration the effective H.T. voltage is $E - V_t$, and the corresponding grid voltage is $\frac{M}{L} \cdot V_t$. (If grid bias is used, its value must be deducted from the voltage $\frac{M}{L} \cdot V_t$.)

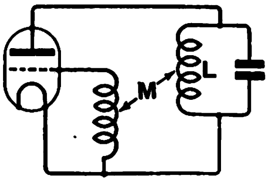


Fig. 1.

To obtain the corresponding grid current we may refer to the characteristics of the valve which give the relation between the plate and grid voltages for constant values of the grid current. Fig. 3 shows some of the curves that have been obtained for an ordinary D.E.R. valve.

Now grid current will flow only when the grid is positive, *i.e.*, during the positive half-cycle of the grid voltage curve. Therefore, if one cycle of this curve is divided into 20 equi-distant intervals, it is only during 10 of these intervals (those belonging to the positive half-cycle) that we shall obtain grid current.

If the anode voltage curve is also divided into 20 equi-distant intervals, then the 10 intervals contained in the negative half-cycle of this curve will correspond to the intervals of the grid voltage curve during which grid current will flow (see above). For each of the 10 intervals the corresponding H.T. and grid voltages can be calculated, and hence the corresponding value of the grid current can be obtained. From these 10 values of the grid current the mean power absorbed in the grid circuit can be calculated, and finally the effective resistance introduced into the oscillatory circuit because of the grid current can be determined.

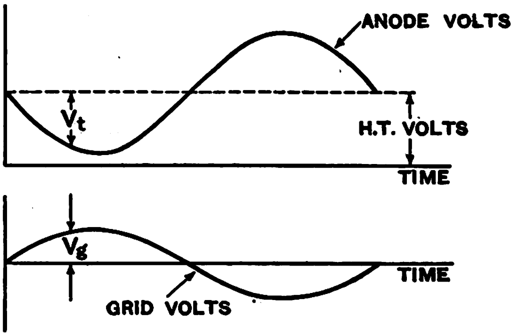


Fig. 2.

The procedure will be understood from the following example.

Example.

The valve used was of the ordinary D.E.R. type, having a resistance of 22,000 ohms and an amplification factor of 9.

The "anode volts-grid volts" curves at constant grid current for this valve are shown in Fig. 3. The curious shape of the curves for 8, 9 and 10 milli-amps. is probably due to ionisation taking place in the valve which is not absolutely "hard."

TABLE I.

Time.	Volts across Anode Coil.	Volts on Anode	Grid Volts V_g	Grid Current I_g*	Power V_gI_g
					Milli-W.
$0.0T$	0	200	0	0	0
$0.1T$	56	144	20	2	40
$0.2T$	105.5	94.5	38.6	3	116
$0.3T$	146	54	52.5	4	210
$0.4T$	171	29	62	9	558
$0.5T$	180	20	65	9.5	618
$0.6T$	171	29	62	9	558
$0.7T$	146	54	52.5	4	210
$0.8T$	105.5	94.5	38.6	3	116
$0.9T$	56	144	20	2	40
$1.0T$	0	200	0	0	0
					2,466

$2T$ = Period of oscillation.

A curve between grid current and volts during one cycle is shown in Fig. 4.

* Assuming no grid bias.

The constants of the oscillator are:—

Inductance of the anode coil = 0.384 henry.

Frequency of oscillation = 1000 cycles/sec.

Mutual induction = 0.138 henry.

H.T. voltage = 200 volts.

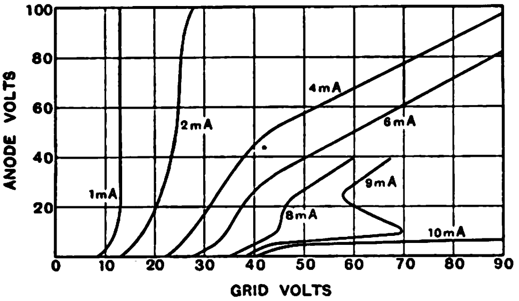


Fig. 3.—*Anode volts-grid volts (grid current constant).*

The peak voltage was measured across the anode coil and it was found to be 180 volts. Let this voltage be V_a.

Peak voltage across the grid coil

$$V_g = \frac{M}{L} \times V_a = \frac{0.138}{0.324} \times 180 = 65 \text{ volts.}$$

R.M.S. current through anode coil:

$$I = \frac{V_a}{\sqrt{2}} \times \frac{1}{\omega L}$$

$$= \frac{180}{\sqrt{2}} \times \frac{1}{0.384} \times \frac{1}{2\pi \times 1000}$$

$$= 0.053 \text{ amp.}$$

The anode and grid voltage cycles are divided into 20 equi-distant intervals, and the value of the grid current for each of the 10 intervals during the positive half-cycle of the grid voltage curve is given in Table I.

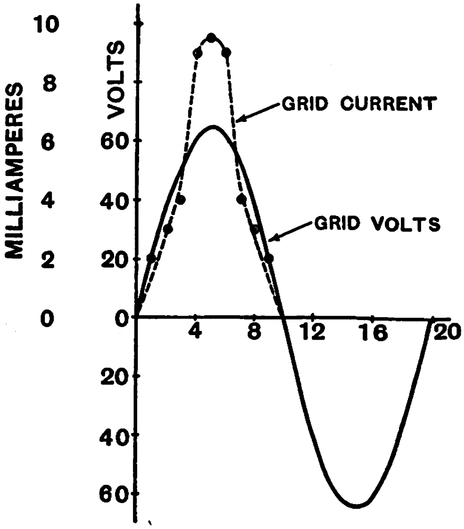


Fig. 4.—*Curves showing grid current and volts during one cycle.*

The voltage across the anode coil at any instant t is given by

$$V_t = V_a \sin \theta$$

where $\theta = \epsilon/T \times 180°$, and T is the time of half-a-cycle.

From Table I. we have that

$$\Sigma_0^T V_gI_g = 2.466 \text{ watts}$$

∴ Mean power (for the whole cycle)

$$= \frac{1}{2T} \Sigma_0^T V_gI_g = 2.466/20 = 0.1233 \text{ watt.}$$

∴ Power absorbed in the grid circuit

$$= W_g = 0.1233 \text{ watt.}$$

∴ Effective resistance introduced into the oscillatory circuit is given by

$$I^2 \times R_{\text{eff.}} = W_g$$

$$R_{\text{eff.}} = \frac{W_g}{I^2} = \frac{0.1233}{(0.053)^2} = 44 \text{ ohms.}$$

If greater accuracy is required, the number of equi-distant intervals taken should be increased.

The method given in this article does not pretend to give a high degree of accuracy. It can, however, be used to give a good indication of the damping due to grid current, and to determine when this damping is becoming excessive.

For greater accuracy the following must be taken into account :—

(1) The distortion due to grid current. The true waveform of the anode oscillatory voltage would have to be determined and analysed by means of Fourier series. Each of the resulting sine curves would then have to be treated separately in the manner indicated in this article.

(2) The voltage induced in the grid circuit owing to grid current. This would lower the effective voltage on the grid from the value that we have assumed, by the amount $\omega L_2 I_2$, where :

L_2 = inductance of grid coil.
I_2 = grid current at the time t.

The actual values of the grid current will therefore be lower than those which have been taken in this article.

The value of $\omega L_2 I_2$ can best be determined by trial and error, since it depends on the value of I_2, which in turn depends on the value of the effective grid voltage.

Substandard Wavemeter Design.

By W. H. F. Griffiths, A.M.I.E.E., Mem.I.R.E.

THERE is a tendency among radio engineers whose chief design responsibilities lie in the direction of traffic rather than standardisation, to approach accurate wavemeter design from the viewpoints of wideness of range covered, decrement, and accuracy *of calibration*. This often leads to the construction of a wavemeter which, although having an extremely low decrement (and consequently a high *apparent* accuracy) and covering, with few range changing operations, an extremely wide range of wavelength, is incapable of *maintaining* the accuracy of its calibration.

Although decrement must, for the accurate *detection* of resonance, be kept low, this must not be accomplished at the expense of permanence of capacity by the simple expedient of maintaining a high ratio of L/C, but rather by keeping the resistance of the circuit as low as possible, so that, for a given decrement, L may be low in order to make possible a high value of C.

The accuracy superiority of wavemeter circuits having high values of capacity cannot be stressed too much, but the temptation to avoid their use is admittedly great, owing to the ease with which inductances suitable for circuits of low capacity can be designed even for a low decrement. This is, of course, explained simply as follows :—

$$\delta \propto \frac{R}{fL}$$

and this may be re-written in the form

$$\delta \propto R\sqrt{\frac{C}{L}}$$

but, for a given frequency, $\sqrt{\frac{C}{L}}$ is inversely proportional to L, whereas the other factor of which the decrement is a function is proportional only to the root of L.*

$$\sqrt{\frac{C}{L}} \propto \frac{1}{L}$$

$$R \propto \sqrt{L}$$

$$\therefore \quad \delta \propto \frac{\sqrt{L}}{L} \propto \frac{1}{\sqrt{L}}$$

Short-wave Design.

This easy method of design is frequently met with in short wave wavemeters, especially where attempts are made to employ, on these bands, a method of resonance detection which introduces a series resistance into the resonant circuit. It is fairly easy, one can see, to swamp the circuit resistance thus highly augmented, by a high value of inductance.

Moreover, in the case of ultra short wave circuits, the difficulty of keeping the capacity high is greatly increased by the fact that the values of inductance required are comparable with, and even limited by, the effective inductance of the variable condenser itself.

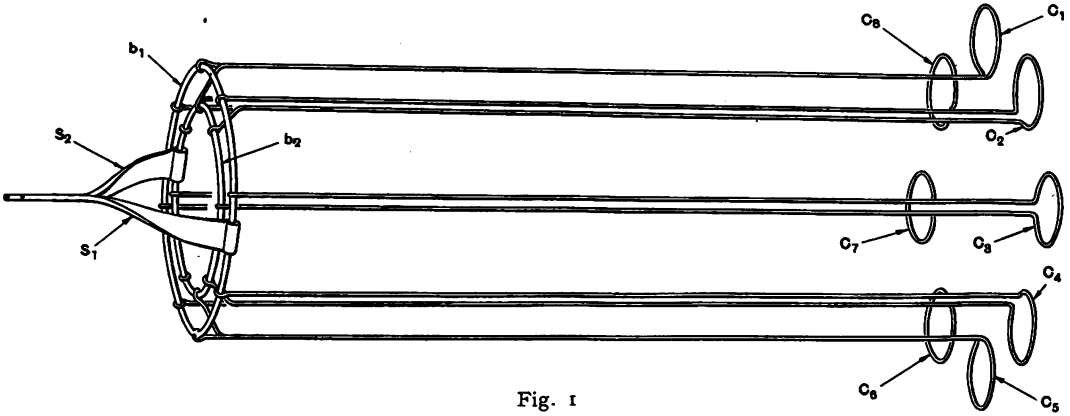


Fig. 1

That it is possible, however, to design a short-wave substandard wavemeter of comparatively high capacity by careful design of the inductances is shown by the following brief notes on a wavemeter designed recently by the author having a range down to 10 metres in which the capacity is not decreased below 240μμF. even at a frequency of 30,000 kilocycles, while the decrement at this frequency is not increased beyond the order 0.01.

In this wavemeter a precision variable air condenser is employed in association with two very compact fixed air condensers. Either of the fixed units may be paralleled with the variable unit (by swinging a strap between two terminals), giving two capacity ranges of 220–440μμF. and 380–600μμF. The capacity change obtained is 1.5μμF. per degree throughout a scale of 180 degrees.

The variable condenser is of the very permanent silica-quartz insulation type, designed to have an extremely low effective resistance and, what is equally important for short-wave wavemeters, a low value of self-inductance. The fixed condensers are of the order 150 and 300μμF., and, since it is, of course, impossible to construct really reliably constant condensers of such low values having mica dielectric, these have to be of air dielectric. Moreover, in order that the effective inductance of the variable condenser shall not be augmented to any great extent by that of the fixed condensers, the latter have to be of very compact and rigid construction. The screening case containing the two condensers is only 9.5 cms. × 7 cms. × 3 cms. and is secured to the main condenser screening case near to the terminals.

Even with this compact construction, however, the inductance of the complete condenser is of the order 0.06μH.—a value quite high enough to render difficult the design of coils suitable for association with the condenser at very low wavelengths.

---

* Within limits of dimensions the inductance of an efficient coil is roughly proportional to the square of its number of turns, while the resistance of a coil at a given frequency is approximately proportional to its number of turns. From this it follows that, as an approximation, R is proportional to $\sqrt{L}$.

A rigid self-supporting coil of 1 cm. diameter copper tube having a single turn 10 cms. in diameter and kept about 25 cms. away from the metallic mass of the condenser screens by parallel ends, is employed to take the wavelength down to 16 metres. This coil has a calculated inductance of about 0.26μH., which is augmented to the value 0.32μH. upon its association with the condenser. The effective resistance of the whole circuit with this coil in use at 16 metres is only 0.12 Ω, corresponding with a decrement of 0.01.

A Novel Short-wave Inductance.

It will be seen, therefore, that in order to increase the range down to 10 metres without decreasing the capacity below 240μμF. (the lower limit of the truly linear portion of the capacity scale) a coil having an inductance not greater than 0.06μH. (0.12μH. when augmented by the inductance of the condenser) is required—an extremely low value for a low decrement coil with a good "pick-up."

The design of coil eventually decided upon takes the form of a number of comparatively fine wire circuits connected in parallel by means of two heavy concentric circular bus-bars b_1, b_2 of Fig. 1. The bus-bars are connected to the terminals of the condenser by the straps S_1, S_2. Each of these circuits consists of slightly spaced parallel leads running for a distance of 28 cms. and terminated in a single turn loop of 2.5 cms. diameter which forms a very effective energy "pick-up" sufficiently far from the metallic mass of the condenser screens. Such a coil has a calculated inductance of about 0.22μH. Eight such coils, C_1 to C_8, are therefore led out horizontally from the bus-bars equally spaced round the circumference of an 8 cm. circle. Their terminating loops are bent up to be in one plane vertically as shown in the drawing.

The fine wire circuits are formed from very hard brass wire in order to obtain a fair degree of geometrical permanence and the whole inductance copper plated, after the parallel circuits were soldered to the bus-bars, to an appropriate thickness to reduce the high-frequency resistance of both wire and soldered joints to a minimum. The complete coil is reinforced and protected by an insulating framework grooved to house the parallel wires.

The eight parallel circuits have a resultant inductance of about 0.03μH.; this added to 0.03μH. in the bus-bars and main connecting straps and 0.06μH. of the condenser gives a circuit inductance of 0.12μH. This permits tuning to 10 metres with 240μμF. The effective resistance of the circuit at 10 metres is of the order 0.1 Ω, corresponding to a decrement of 0.012.

Even with this value of capacity it will be seen that a change of, say, ±0.5μμF. will produce a wavelength inaccuracy of about 1 part in 1000, and if the capacity had been reduced to about 80μμF. in order to use for 10 metres an ordinary single turn coil such as that described for 16 metres, the corresponding probable wavelength uncertainty would have been 3 parts in 1000.

If a direct method of resonance detection must be employed in a wavemeter such as this, where the values of reactance are so low, it should take the form of a parallel load. With the values of reactance met with in this wavemeter, for instance, a load such as that of a thermionic voltmeter (of the order 0.75×10^6 Ω) may be safely shunted across the entire circuit without augmenting, appreciably, its decrement. Even the dielectric losses due to a possible bad phase angle of the materials of valve and socket are not felt because of the high value of circuit capacity.

An objection, however, to the method is that of a possible change of inter-electrode capacity either with the age of the valve or its replacement. This is also, of course, rendered less serious by the high value of circuit capacity.

Conclusion.

In conclusion, the author wishes to emphasise the fact that the foregoing notes assume the use of the best possible grade of variable condenser and if, for reasons of economy, the quality of the condenser is reduced as well as its value, nothing approaching accuracy may be expected.

The author's thanks are due to Messrs. H. W. Sullivan, Ltd., for permission to publish details of the short-wave coil and to W. G. Hill for much of the experimental work which led to its final design.

Reactance and Admittance Curves.

Applied to Tuned Circuits With and Without Resistance.

By L. T. Bird.

PART I.—CIRCUITS WITHOUT RESISTANCE.

SINCE wireless energy is of an oscillatory nature it is inevitable that the tuning of circuits should be of fundamental importance in wireless engineering. Tuning, however, is so easily effected in simple cases in practice that the underlying theory is often somewhat neglected with the result that more complicated circuits present needless difficulties. What is very often needed is a ready mental picture of the behaviour of a given arrangement of apparatus over a certain range of radio frequencies. Reactance-frequency and Admittance-frequency curves provide such a picture. To draw these accurately may in some cases involve a certain amount of mental labour, but when their development is thoroughly understood it is nearly always possible to make without any calculation a fairly correct rough sketch which will show in a general way what the characteristics of the circuit are. Very often this is all that is required.

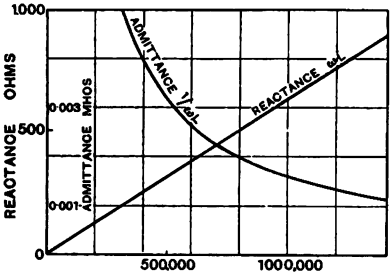


Fig. 1.

Reactance and admittance curves are evolved from considerations of the fundamental properties inductance and capacity.

The inverse of reactance (*i.e.* $\frac{1}{\text{reactance}}$) is called admittance. In a coil this is equal to $\frac{1}{L\omega}$, which is the value of the current to induce unit alternating voltage in a given inductance. The reactance and admittance of a given coil obviously vary with the frequency, and the curves of Fig. 1 show this variation for an inductance of .0001 henries, or 100 μH., as the frequency is varied from 0 to 1,400,000 cycles per second.

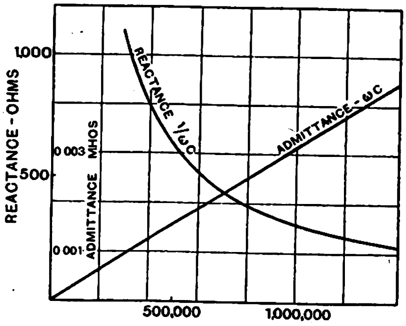


Fig. 2.

The reactance of a condenser $= \frac{1}{C\omega}$. The admittance is the inverse of this and hence is equal to $C\omega$. The curves of Fig. 2 show the variation in reactance and admittance of a capacity of .0005 μF. as the frequency increases from 0 to 1,400,000 cycles per second.

Combinations of Inductance and Capacity.

For the purpose of tuning, inductance and capacity are used in combination, and it is in this connection that reactance and admittance curves prove to be of value.

Inductance and Capacity in Series.

Whilst in the case of inductance the voltage vector is 90° ahead of the current vector, it is 90° behind in the case of capacity. If, therefore, a capacity is connected in series with an inductance the two pieces of apparatus will have a common current, and the vector diagram will be as shown in Fig. 3a.

The important fact demonstrated by this figure is that in this arrangement the two voltage vectors are always in opposite directions, *i.e.*, the two voltages are half a cycle out of phase, so that when one voltage is positive the other is negative, and hence the voltage across the complete combination is always the difference of these two. If the common current be unity the maximum value of these voltages will for a given frequency be given directly by the respective reactance diagrams of the inductance and capacity. If these two diagrams be subtracted the resulting figure will show the voltage across the combination for any particular frequency in the range considered when the current is one ampere—*i.e.*, it will be the reactance diagram of the combination.

Fig. 3b shows this diagram for the arrangement of the coil and condenser in series. In this figure all the values of the reactance of the condenser are shown as negative to indicate the subtraction, and this convention will be followed in other examples.

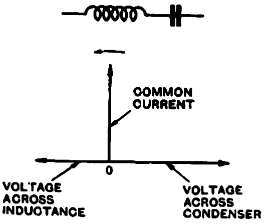


Fig. 3a.

The admittance diagram is drawn by calculating the inverse of the values of reactance for a number of different frequencies and plotting the points. Thus at a frequency of 9×10^5 cycles the reactance is 208 ohms. Hence at this frequency the admittance is $\frac{1}{208}$ mhos, this value being plotted to give a point on the admittance curve (Fig. 3b).

Fig. 3b shows clearly that at a frequency of 714,000 cycles (approx.) the reactance is zero and the admittance infinitely great. This means that whatever current *of this particular frequency* passes through the combination, the voltage across it will be zero; and, conversely, whatever voltage of this frequency is applied to the combination the current will be infinitely great. This arrangement is therefore termed an acceptor circuit and the phenomenon is referred to as "series resonance." The explanation of it is that for this frequency the voltage across the condenser is not only opposite to that across the inductance, but is exactly equal to it at any instant. The net voltage is therefore always zero. Bearing in mind this fact, it is not difficult to deduce the value of the resonant frequency for given capacity and inductance.

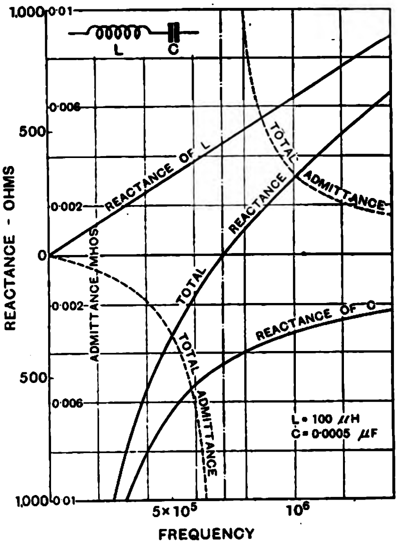


Fig. 3b.

Since voltage across inductance $= L\omega I$
and „ „ capacity $= I/C\omega$.
it follows that

$$f = \frac{1}{2\pi\sqrt{LC}} \text{ cycles per second,}$$

L being measured in henries and C in farads.

Capacity and Inductance in Parallel.

Connecting an inductance in parallel with a condenser establishes the condition that the voltage across the one is always the same as the voltage across the other. The vector diagram is shown in Fig. 4a, the voltage vector being common to both and the current vectors lying in opposite directions, *i.e.*, the current through the inductance is exactly half a cycle out of phase with the current

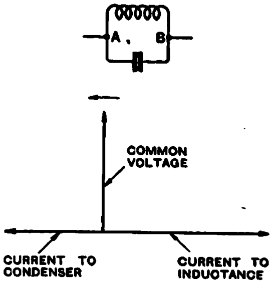


Fig. 4a.

through the capacity. In other words, for a given frequency, although both currents reach maximum and minimum values at the same instant, they are of opposite sign; when current is flowing through the inductance from *A* to *B* the condenser current is from *B* to *A*, and the net current in the common lead to the combination will be the difference of these two.

If the maximum voltage between *A* and *B* is one volt, the maximum values of these currents at any particular frequency will be given by the respective admittance curves of the inductance and capacity when separate. The curve obtained by plotting the difference between these values will therefore be the admittance curve of the combination.

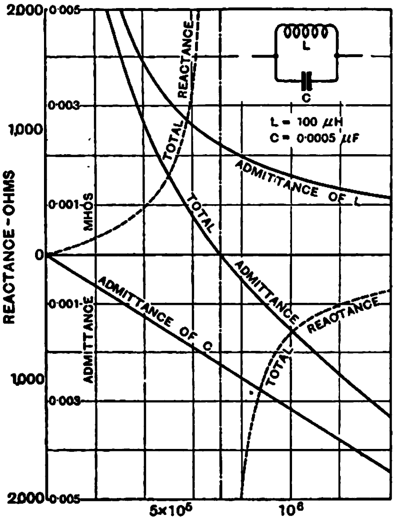


Fig. 4b.

This curve is shown in Fig. 4b for the same coil and condenser, but now connected in parallel. Again, the values of the admittance of the condenser are shown as negative and the algebraic sum of the two curves drawn.

The reactance diagram is obtained by calculating for a number of points the inverse of the admittance and is shown also in Fig. 4b.

These two curves show that at a definite frequency the admittance of the combination is zero and the reactance infinitely great. This means that a very large voltage of this frequency might be applied to the circuit and the current in the common lead would be zero. For this reason the circuit is called a rejector circuit and the condition is called parallel resonance.

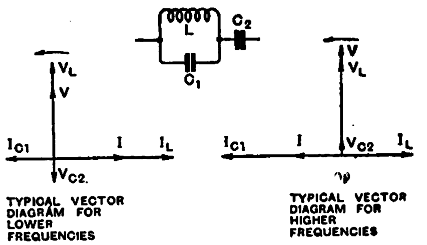

L
C₁
C₂
V_L
V
I_{C1}
I
I_L
V_{C2}
TYPICAL VECTOR DIAGRAM FOR LOWER FREQUENCIES
V
V_L
I_{C1}
I
V_{C2}
I_L
TYPICAL VECTOR DIAGRAM FOR HIGHER FREQUENCIES

Fig. 5a.

It should not, however, be imagined that because the current in the common lead is zero that there is no current in either inductance or capacity. In fact the currents in them may be very large according to the magnitude of their respective admittances; but being equal and opposite, what may be termed the supply current (*i.e.*, the current in the common lead) is zero.

The value of the resonant frequency may in this case be determined by considering the equality of these two currents.

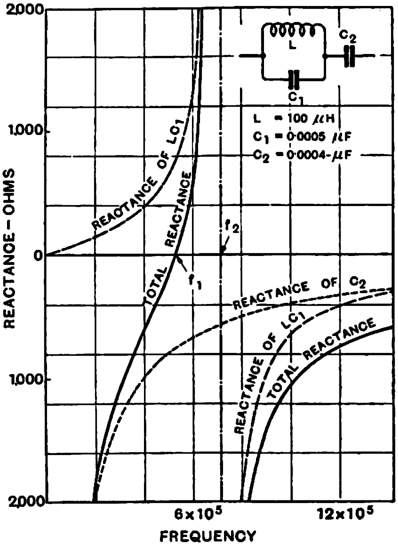


Fig. 5b.

Since $I_c = VC\omega$

and $I_L = V/L\omega$

it follows that $f = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}$

In a series or parallel circuit either inductance or capacity may be made variable, and the circuit adjusted so that its resonant frequency is any desired figure. This is what is meant by tuning a circuit.

More Complicated Circuits.

This method of analysis is particularly well suited to more complicated circuits about which it is often difficult to formulate general ideas at first sight. Consider the arrangement (shown in Fig. 5a) of a rejector circuit connected in series with a condenser. It is perhaps difficult to say immediately how such a combination will behave over a range of frequencies without drawing reactance or admittance curves.

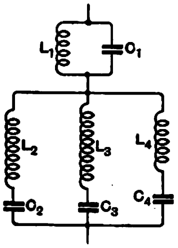


Fig. 6a.

$L_1 = 62.5\ \mu H.$ $C_1 = 0.001\ \mu F$
$L_2 = 250\ \mu H.$ $C_2 = 0.0002\ \mu F.$
$L_3 = 250\ \mu H.$ $C_3 = 0.001\ \mu F.$
$L_4 = 120\ \mu H.$ $C_4 = 0.0002\ \mu F.$

It will have been observed that for a series arrangement *reactance* curves are combined and for a parallel arrangement *admittance* curves are combined. This is because reactance curves do, in effect, show voltages for unit current, and in the series arrangement voltages add (the current being the same for both pieces of apparatus). In the case of the parallel circuit it is the currents which combine, and hence admittance curves are added.

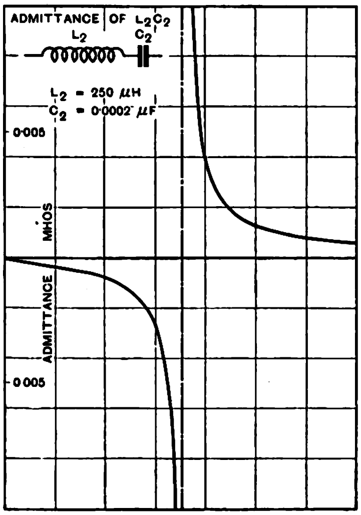


Fig. 6b.

Bearing this in mind the circuit of Fig. 5a should not present any difficulty. Consider, first, that portion made up by the inductance L and capacity C_1 in parallel. Addition of the admittance curves of L and C_1 will give the admittance of the combination of these two. The inverse of this will as before, give the reactance curve of L and C_1 in parallel. Circuit LC_1 is in series with condenser C_2. It is therefore the reactance curve of C_2 which should be combined with the reactance curve of LC_1. Exactly how the reactance curve of C_2 should be treated is indicated by the vector diagrams of the circuit (Fig. 5a). Considering circuit LC_1 it will be noted that for frequencies up to resonance the "supply current" I is ¼ cycle behind the common voltage V_2. Beyond resonance it is ¼ cycle ahead. This current is also the current through the condenser C_2. The voltage across condenser C_2 lags behind this current by ¼ cycle. Putting this voltage vector V_{c2} in its proper position in the diagram we find that up to the frequency of resonance in LC_1 the two voltage vectors are ½ cycle out of phase, and therefore subtract giving the vector V.

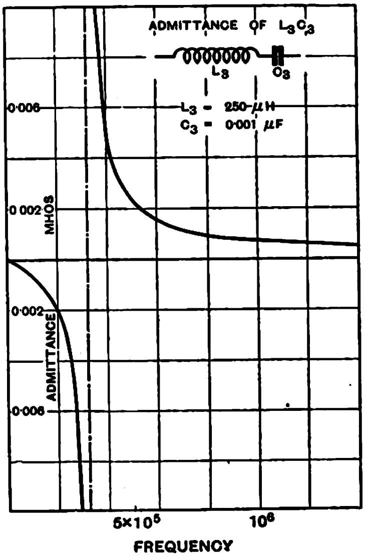


Fig. 6c.

For frequencies above this they are in phase and add. It will therefore be correct to show the reactance of C_2 as negative throughout and to take the algebraic sum of the two reactance curves. (In general it may be said that admittance is shown as negative when the current leads and the reactance negative when the voltage lags.)

The final curve (Fig. 5b) is the required reactance curve of the whole circuit and shows immediately that the circuit is an acceptor to one frequency f_1 and a rejector to another f_2, and may therefore be usefully employed for the purpose of suppressing undesired signals on a given wavelength in favour of desired signals on a different wavelength provided correct values are chosen.

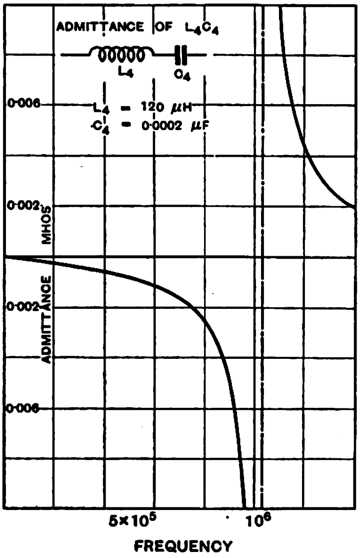


Fig. 6d.

The reactance curve of a rather more complicated circuit (Fig. 6a) is developed in Figs. 6b to 6h, the process being as follows. The admittance curves of the acceptor circuits L_2C_2, L_3C_3 and L_4C_4 are obtained in the manner already shown (Figs. 6b, 6c and 6d). As these circuits are in parallel their admittances are added, the resulting curve being shown as Fig. 6e. The inverse of this is taken, giving the reactance curve of Fig. 6f. The reactance curve of circuit L_1C_1 is next drawn (Fig. 6g) and this on addition to curve of Fig. 6f gives the reactance curve of the complete circuit (Fig. 6h).

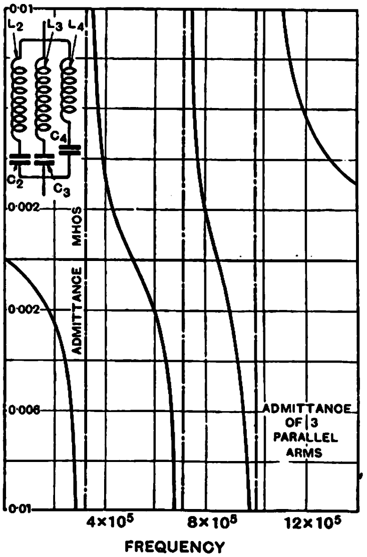


Fig. 6e.

This final diagram demonstrates quite a number of things. At a haphazard guess one might have said that such a circuit would have but four natural frequencies, three as an acceptor and one as a rejector. Actually, as the reactance diagram shows, it has seven natural frequencies, four as an acceptor and

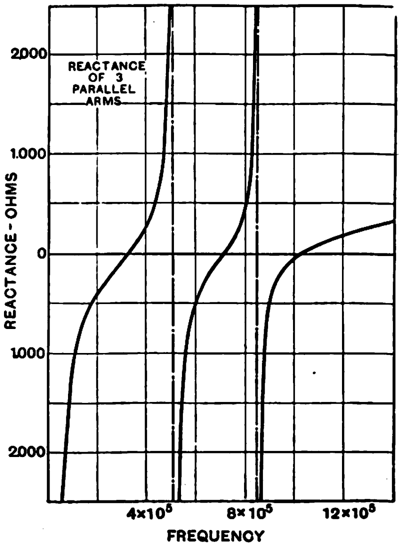


Fig. 6f.

three as a rejector. It should also be noted that none of the series resonant frequencies coincide with the tune of L_2C_2, L_3C_3 or L_4C_4 separately, since the whole circuit is in series resonance, not when either of these circuits has zero reactance, but when the reactance of the three in parallel is equal and opposite to the reactance of circuit L_1C_1.

PART II.—RESONANT CIRCUITS WITH RESISTANCE.

Up to this point only those circuits have been considered which possess simply inductance and capacity. Actually every coil has a certain amount of resistance, and in every condenser the insulating medium possesses conductance. These quantities are usually small in comparison with the reactances or admittances with which they are combined and hence are often assumed to be zero. However, when these assumptions are made in theory, strange conclusions are reached, such as infinitely large currents produced by zero voltages and *vice-versa*. To make theory fit more closely to practice it is necessary to take the effects of resistance into account.

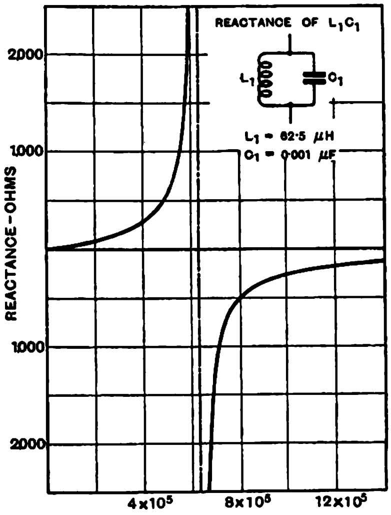


Fig. 6g.

Resistance in Series with an Inductance.

Case (a) when the current remains constant and the frequency varies.—Suppose the current to remain at one ampere and the frequency to be increased. *OA* (Fig. 7a), representing the voltage across the resistance, will remain of constant length. The line *AC*, however, representing the reactance voltage, will increase in length as the frequency increases to such a position as *C'*, with a consequent increase in the length of *OC*, and an increase in $\widehat{AOC}$ (the angle of phase difference between current and total voltage) to a limit of 90° (*i.e.*, in the case when the frequency is so high that *AC* is so long as to make *OA* negligible in comparison).

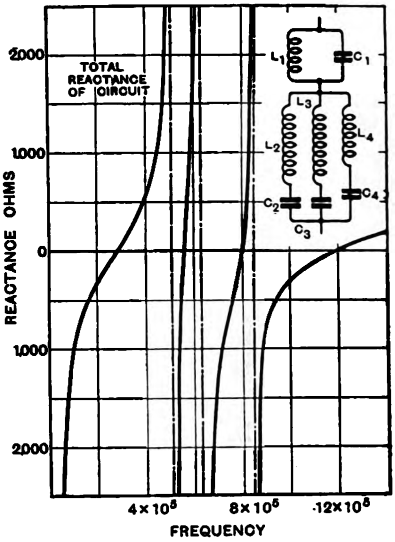


Fig. 6h.

Since *OC* represents the value of the total voltage when the current is 1 ampere, its length is a measure of the ratio between voltage and current at the frequency chosen. This ratio is called the impedance of the arrangement (impedance corresponds to reactance, the latter word, however, being reserved for apparatus like pure capacity and inductance). This triangle may therefore be utilised as follows in plotting the impedance-frequency curve of the combination.

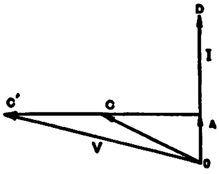


Fig. 7a.

Draw as before the reactance curve *OB* of the inductance (Fig. 7b). Now draw a line *AA'* parallel to the axis of frequency at such a height AO above it as represents on the scale of the diagram the value of the resistance. Select a frequency and erect an ordinate FG mark off from A along AA' a length AC equal to FG. Then OC represents the impedance of the arrangement. Produce FG to H so that $FH = OC$. H is then a point on the impedance diagram. If this process be repeated for a number of points the impedance curve may be drawn through them.

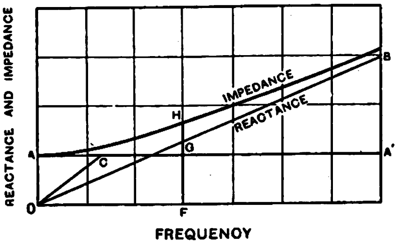


Fig. 7b.

Case (*b*) *when the total voltage remains constant and the frequency varies.*—Suppose the voltage remains constant at unity and the frequency increases. The shape of the triangle will vary, but this time the line OC representing the total voltage will remain of constant length. This line being constant and $\widehat{CAO}$ being always a right-angle, point A will always be somewhere on a semi-circle having OC as a diameter (Fig. 7c). As the frequency increases the reactance becomes larger, whilst the resistance, of course, remains the same, *i.e.*, AC in the diagram becomes larger in comparison with AO. A therefore moves to such a point as A' on the semi-circle.

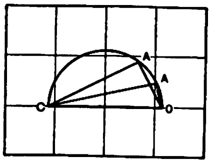


Fig. 7c.

So far this vector diagram is concerned only with voltages and gives no information about the resultant current. This latter is a most important quantity, since it is the ratio of applied voltage to resultant current with which we are concerned. The resultant current may be determined from the two following considerations:—

(1) The current must necessarily be in phase with the voltage it produces across the resistance.

(2) Its value may be found by dividing the value of this voltage by the resistance in ohms.

Hence for a given frequency the resultant current vector will lie in the same direction as OA, and its length will be found by multiplying the length of OA by the factor $1/r$; such a current vector is shown as OD in Figs. 7a and 7d.

It is instructive to note what happens to the position of the point D as the frequency is changed.

(1) If the current remains constant D remains fixed (Fig. 7a), since OA is constant.

(2) If the voltage is constant the line OA (Fig. 7d) changes in both length and direction as the frequency changes.

To find the path of point D:

From D draw DE parallel to AC and cutting OC produced in E. Triangles EOD and COA will be similar, and hence

$$OE/OC = OD/OA$$

$$\therefore \quad OE = \frac{OD \,.\, OC}{OA}$$

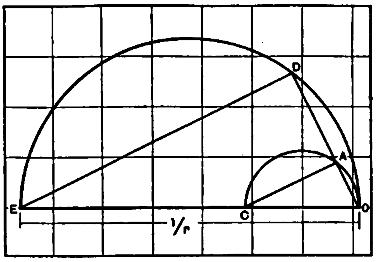


Fig. 7d.

$$\text{Now} \quad OD = OA \times 1/r \text{ and } OC = 1$$

$$\therefore \quad OE = \frac{OA \times 1/r \times 1}{OA}$$

$$= 1/r$$

Now EDO is always a right-angle, therefore D lies on the circumference of a semi-circle whose diameter is $1/r$ units in length. This diagram will be referred to later, where it is used for the purpose of finding the direction of OD for different frequencies, its length having already been determined from an admittance diagram.

Resistance in parallel with a condenser.—The "leaking" of electricity from one element of a condenser to another (this property is often referred to as "leakance") is treated as the combination of capacity and resistance in parallel, since the effect is the same as if the insulation were perfect but a high resistance were connected from one side of the condenser to the other.

Case (*a*).—*If the voltage remains constant* the current through the resistance will be the same whatever the frequency. Hence *OP* (Fig. 8a) will remain of constant length ($1/R$ units) and *PQ* will increase as the frequency increases, *OQ* representing the total current. The drawing of the admittance curves of the arrangement is a similar process to that of drawing the impedance curve of an inductance. The value of the current through the resistance being independent of the frequency it will appear (Fig. 8b) on the admittance curve as a straight line *PP′* parallel to the axis of frequency. By marking off along *PP′* the value *PQ* of the admittance of the condenser for a selected frequency, the value *OQ* of the total admittance may be obtained and plotted on the admittance curve. The impedance curve is obtained by calculating the inverse of a number of values of admittance and drawing a fair curve through the points so plotted.

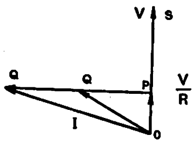


Fig. 8c.

Case (*b*).—*If the total current remains constant* the length of *OQ* (Fig. 8c) will remain the same, *P* will move on a semicircle described on *OQ*, and since *OP* represents the current through the resistance, the voltage across it (which is also the voltage across the condenser) will be represented by a line *R* times as long. By a construction similar to that used in the inductance case it will be found that *S*, the end of the voltage vector when the total current remains constant at unity, lies on a semi-circle whose diameter is *R* volts. Thus again a semicircle diagram may be applied to determine the angle of phase difference between total current and applied voltage if the magnitude of the current be known (*e.g.*, from an impedance diagram).

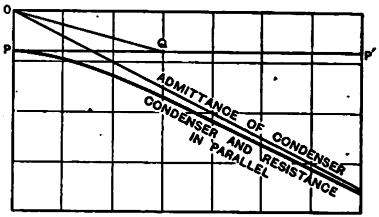


Fig. 8b.

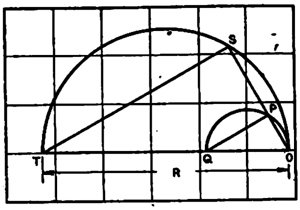


Fig. 8c.

(*To be concluded.*)

Screened-Grid Valves

Informal Discussion at the I.E.E. Wireless Section.

ABSTRACT.

THE concluding meeting of the Session for the I.E.E. Wireless Section was held on Wednesday, 2nd May, Lt.-Col. A. G. Lee, O.B.E., M.C., the Section Chairman presiding, when the meeting took the form of an informal discussion on "Screened-Grid Valves."

In opening the meeting, the Chairman announced that Commander J. A. Slee, C.B.E., had been nominated as Chairman of the Section for the next session.

The discussion was opened by **MR. M. G. SCROGGIE, B.SC.**, who said that the screened-grid valve had only attracted attention within the last eight months. Following on initial work by Schottky in 1919, Hull had shown in 1925 that very large high-frequency amplification could be obtained by means of screening. The patent of Round, of May, 1926, covered those in common use in this country.

The application which had received most attention was high-frequency amplification. Up to the advent of the screened-grid valve the only methods of high amplification were by neutrodyne and supersonic. With attention to detail of design, it was possible to get an amplification of 40 per stage with neutrodyne. Two stages were difficult to handle with the utmost efficiency. More than two stages were only practicable for increase of selectivity. The balance for neutrodyne adjustment was not constant over a band of frequencies. The supersonic gave greater amplification, but was not free from faults. Unless a high-frequency stage was interposed, there was liability to trouble due to interference at the frequency of the intermediate-frequency amplifier.

The screened-grid valve had brought back the straight amplifier. Whereas the triode had an anode-grid capacity of about 6 $\mu\mu$F, the screened valve due to Hull had only one-thousandth of that value. Commercial products were intermediate. Each stage of the amplifier should approach complete metal enclosure, even the commoning of batteries was defective.

Although the usual practice of tuning was by fixed coil and variable condenser, R. T. Beatty had shown that fixed capacity and variable inductance gave better stability over the band.

The curve relating maximum amplification with frequency drooped towards the higher frequency, as in Fig. 1 (full line). The actual amplification used should be that of the lower curve (dotted). With a certain distance between these curves it was possible to get reasonable tuning and stability over the range. Tuning by variable inductance made this easier.

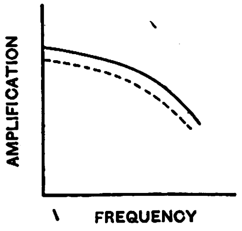


Fig. 1.

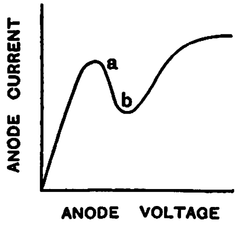


Fig. 2.

With the screened valve the amplification obtained was made up of two parts (a) due to the valve without reaction, and (b) that due to reaction. With a single stage, using the S.625 valve, the latter was less than the former. With two stages the latter tended to take charge and with three stages oscillations were liable to occur unless loss was introduced; he doubted if there was any need for more than three stages. For stability the inter-electrode capacity must go down.

The use of the screened valve for intermediate frequency amplification (of supersonic) was an obvious application.

The use of the screened valve at low frequencies had not been much dealt with. The anode-current, anode-voltage, characteristic curve of Fig. 2 suggested the region a-b as being suitable for resistance amplification with suitably chosen constants, as being capable of yielding very large amplification. The position of the portion of the curve to be used, however, was liable to vary with different valves. The normal flat portion of the curve had not been much used for low-frequency. Single note amplification with S.625 had advantages, and it could obviously be used with a sharply tuned resonant circuit to give large amplification. The pentrode type of valve recently introduced seemed, however, more adapted for use on the low frequency end.

Details of design of the valve itself the speaker left to valve designers and makers, but he would raise the query as to which electrode should be separated, pointing out the differences of practice that prevailed in this matter.

Dr. J. Robinson, who continued the discussion, asked what was the screened-grid valve doing. Its curve was complicated, and he preferred simplicity. The screened valve could give huge amplification, but what trouble was involved? The tendency of design in broadcast receivers was towards simplicity. Mr. Scroggie's reference to the use of a limited part of the curve suggested difficulty. The screened valve eliminated internal capacity, but there were other ways of doing this. It was possible to do it by simpler and cheaper means—by the introduction of an equivalent capacity, identical with the grid-anode capacity. This could be done by duplication of the anode and grid, when it was possible to get, without neutrodyning, the performance of a valve free from capacity.

Mr. C. F. Phillips said that in normal operation of the screened valve—as in H.F. amplification—the flat portion of the curve was utilised. Mr. Scroggie's reference to the descending portion of the curve was only to its use with resistance coupling for low frequency. In using the flat portion with suitable valves, valves of widely differing characteristics could be interchanged without difficulty. The reason for the kink was obvious, and the introduction of the space-charge grid smoothed out this portion. The tetrode of to-day was the forerunner of future developments. The aim should be not to do fresh jobs, but to make one valve do its job better. Referring to the pentode with 20,000 ohms internal impedance for use as an output valve, he did not think this was dreadful. The behaviour on the flat top of the characteristic was different from the triode, and he doubted if the high impedance of the pentode mattered much in practice.

The "mains" set had come to stay. The valve must become capable of operation from A.C. mains, and he hoped for information from valve makers as to the possibility of screened valves with cathodes heated either directly or indirectly by alternating current.

Referring to the matter of the separate lead, he said the Marconi S.625 had the anode and screen coming out together at one end. Hull led the screen out at the top alone and the anode at the bottom. The Mullard valve had the anode coming out at the top and the screen at the bottom.

Capt. P. P. Eckersley asked of what type would be the receiver of the future. The screened valve had made a revolution in high-frequency amplification. He suggested that the need was for a "trouble-free" receiver, listening to a transmitting station within its own service area. The future receiver should have a band-width giving 7½ or 10 kilocycles of sideband, the whole band being capable of moving across the spectrum. Did the screened grid valve help achievement of this?

Lt.-Col. K. Edgeworth referred to conditions of reception in Khartum. There being no local broadcast, he was interested in the picking up of broadcast on short waves—of 20 to 30 metres. Difficulties varied with different localities. Fading was a great trouble, but he believed there was a device to minimise fading by limiting the too-strong signals. There was a need in such places for a short-wave receiver giving an amplification of 40 in its H.F. stages. He invited information on the application of the screened valve to this problem.

Mr. Baker spoke of conditions in India, where the only hope was in short waves. It was essential to have some progress towards high-frequency amplification. He had found a Reinartz circuit was sometimes satisfactory on the short wave station of Chelmsford. He had one set using a Mullard screened-grid valve as a high-frequency amplifier, but found the amplification low. He was endeavouring to get a two-stage amplifier and would be glad of assistance.

Mr. Harley said the screened-grid valve had two properties. One was the elimination of internal capacity and the other was the enormous amplification. It was possible to use one without the other. An efficient H.F. amplifier could be made without using the screen, but it tended to be unstable unless damping was employed. A suitable arrangement might be two stages, the first orthodox and the second unscreened.

With reference to the three types, the Mullard valve was made to fit standard sockets. The anode *must* be spaced from the grid, while the screen could come out anywhere.

He also suggested combined capacity and inductance tuning by variometer and condenser coupled and operated together.

Mr. J. H. Reyner, referring to the different types of screened valve, said he preferred the four pins at the bottom and anode at the top. The public hesitated to use those not applicable to an ordinary holder. From the designer's point of view, in arranging for two wavelength ranges (*e.g.*, London and Daventry), variometer tuning was not very practicable. It was possible to use combinations of capacity and inductance as in Loftin's circuit. He had used a smaller coil with reaction in this way and, the reaction varying with tune, the set remained below oscillation over its range. Any practical ideas of increasing selectivity would be welcomed. He found the amplification so large that combinations to help selectivity should be good. He suggested a tuned-anode stage coupled by a small condenser to a circuit of low damping.

Mr. Henderson spoke of the help which the screened valve gave by removing reaction. Another point was that it used tuned anode coupling, and simplified change of wavelength range by the use of a single coil instead of a transformer or coils of many terminals.

Lt.-Col. Fuller asked to what extent high-frequency amplification could be usefully obtained. He was interested in the independent cathode. Was it intended that this independence was only in the set, and did not involve independent sources?

Mr. F. S. Barton enquired as to the extent to which the screened valve could be used to prevent back coupling to the aerial, and how far it was commercially possible to "gang" high-frequency stages to get satisfactory amplification over a band.

Mr. S. R. Mullard referred to differences in type. The various groups of makers differed in their practices, but he hoped for standardisation. He also hoped manufacturers would get together on main types. Type numbers meant little, and different practices in this respect should be brought into line.

Mr. E. H. Shaughnessy asked what was the amplification factor of the screened valve, and what was the amplification per stage for one, two, or three stages. Was there any reasonable limit to the number of stages that could be used efficiently?

Mr. Sowter enquired if, in carrying amplification beyond a limit, the introducer had come across the Schottky effect. The effect varied with the filament. Had Mr. Scroggie any information on the different types of filament?

Mr. Cosgrove said that the anode and screen coming out together at one end had advantages for short waves on account of the low capacity between grid and screen. Such screened valves had been used on short waves, but he had no figures available.

Mr. Robinson sought information as to the number of stages from the set-maker's point of view. Several stages tended to become too selective, or, if the coils had losses, to drop amplification. With two stages the selectivity was too great for use on broadcast with low-loss evils. More than two stages became difficult to tune.

Mr. L. H. Bainbridge Bell enquired as to the consistency of different types of screened valves. He was interested in two high-gain amplifiers, closely matched, and feared the possibility of complications due to lack of uniformity. The liability to non-uniformity seemed greater with the assembly of the Marconi type. This point was also important to set makers and users for replacements.

Mr. Scroggie briefly replied to several of the points raised by other speakers in the discussion.

The reference to the use of the downward part of the curve only applied to resistance-capacity coupling for low-frequency work. For high-frequency amplification the screened valve gave definite simplification, especially from the user's point of view, and provided stability with greatly increased amplification.

Dealing with the number of stages that were practicable, he said that if the stages were made inefficient more stages up to five or six could be used. If the selectivity of each coupling were so chosen as to give a cut-off at a suitable frequency, the whole amplifier gave a better band and cut-off than fewer sharply-tuned stages. They were also better for ganging than sharply-tuned amplifiers.

As regards Col. Edgeworth's query, the screened-grid valve was more efficient for short waves than were other types. A satisfactory amplification of 2 or 3 had been got on 20 metres. The fading control method needed large high-frequency amplification and the possibilities of the screened valve in giving big amplification brought this nearer.

The advantage claimed for the 4-pin type was possibly a disadvantage if inserted into a wrong set.

In reply to Mr. Sowter, he had no note of the Schottky effect, although Hull had mentioned it, but Hull's valve had much lower internal capacity. He did not think the close uniformity desired by Mr. Bainbridge-Bell could be obtained at present.

In closing the discussion, the Chairman referred to the need for development of screened-grid valves, and considered that a very useful field was being opened up.

On the motion of the Chairman, Mr. Scroggie was cordially thanked for his introduction and summing up of the discussion.

Book Reviews.

PITMAN'S TECHNICAL DICTIONARY of Engineering and Industrial Science in Seven Languages. To be completed in about 36 fortnightly parts. Published by Sir Isaac Pitman & Sons, Ltd., London. Price 2/6 each part.

The first number of this dictionary of technical terms is mainly of an introductory nature and includes a comprehensive section of alternatives, idioms and technical phrases peculiar to the different languages, a glossary of adopted words, phrases in common use in technical writing and in advertising, a list of abbreviations of technical and scientific terms, and the first instalment of a most valuable dictionary in English, French, Spanish, Italian, Portuguese, Russian, and German. If we may judge by the first number, this publication will prove one of the best and most comprehensive of foreign technical dictionaries that has yet been published.

WIRELESS PRINCIPLES AND PRACTICE. By L. S. Palmer, M.Sc., Ph.D., pp. xi.+504, with 307 Figs. Longmans, Green & Co., Ltd. 18s. net.

The author, who is now Head of the Department of Pure and Applied Physics at the Manchester College of Technology, was formerly a radio engineer in the Admiralty, and is thus well qualified both theoretically and practically to write an authoritative text-book on Wireless. There is a happy combination of theory and practice throughout the book. It is a book for the serious student who wishes to obtain a thorough knowledge of the subject and is not afraid of the necessary mathematics, and it should form an excellent text-book for students at those Universities and Technical Colleges at which Wireless Telegraphy can be studied either as a part of the graduate course or as a post-graduate subject. The book is well printed and well illustrated, and each chapter concludes with an extensive bibliography. After two short chapters on wave motion and oscillatory circuits, Chapter III deals with wireless circuits and aerials. We think that a page or two might have been profitably devoted to the A.C. transmission line as an introduction to the equivalent reactance of an aerial. Chapter IV deals mathematically with special circuits such as acceptors, rejectors, filters, etc.; coupled circuits are dealt with by the method devised by the reviewer and described by him in the *Electrical World* of New York in 1916 (p. 368, August 19). We think that a reference to this paper should have been given. The theory, design, and manufacture of valves, the spark, arc, and alternator methods of generating high-frequency current, the valve as an oscillator, detector, and amplifier are dealt with in succeeding chapters. The chapter on electromagnetic theory will prove the most difficult to most readers. We think that the following statement on page 249 is somewhat misleading: "Now, with a current in a wireless aerial or in a submarine cable, there is a sideways dissipation of energy, and consequently the current in the direction of the antenna or cable diminishes with distance along the wire. Maxwell considered the dissipation of energy in the surrounding dielectric medium as resulting from a 'displacement' δ of the electric charges in the atoms of the dielectric." Displacement is not necessarily associated with dissipation of energy, but was conceived by Maxwell as an explanation of the capacity of the medium. The current along a submarine cable would vary from point to point even if the dielectric were perfect, that is, if it involved no dissipation of energy.

The book concludes with chapters on wireless telephony and directional wireless, the latter going into the subject very thoroughly.

In view of the extensive bibliographies, involving many foreign references, the misprints appeared to be very few; we noticed Schalze, Moulin and Belleseize instead of Schulze, Moullin, and Bellescize. The author gets round the difficulty of finding an English equivalent for "Ziehen" by using it as if it were an English word. Why should we not use the good English word "pulling" for this phenomenon? One would soon get used to it, and it has the advantage that most English people can pronounce it.

G. W. O. H.

THE INSTRUMENT WORLD, a new journal for designers, makers, dealers, and users. Published monthly, price 6d.

The first number of this new publication, which is stated to be the first trade and technical journal in this country to be devoted exclusively to scientific and industrial instruments, contains an interesting article on the value of proper scientific instruments in industrial research, descriptions of recent improvements in surveying instruments, the theory of ultra-violet therapy and some of the apparatus used for the production of artificial sunlight, echo sounding gear, and other subjects. There is also the introductory portion of a dictionary of technological science, which will, no doubt, prove a valuable source of reference.

INTERMEDIATE ELECTRICITY AND MAGNETISM. By R. A. Houston, M.A., D.Sc., pp. x+170, with 155 Figs. Longmans. 4/6.

This book treats of the subject up to the Intermediate or First Science Standard of the different Universities. It is clearly written and well illustrated but in our opinion attempts too much. An elementary book of 154 pages (the remaining pages are devoted to examples and index) which commences with lodestones, iron filings, gold-leaf electroscopes and the electrophorus should not be tempted to deal even briefly with positive or canal rays nor with isotopes, and the page devoted to the test of a crystal detector might have been more profitably, if less popularly, devoted to a more detailed discussion of some of the fundamental principles of electricity and magnetism.

The author is a well-known teacher and writer on various branches of physics and we were especially interested to see how he dealt with the difficult problem of the magnetic properties of iron. We must confess, however, that we were very disappointed, the method adopted is self-contradictory and can only confuse any student who tries seriously to follow it. As this is a matter of some importance we may be excused for going into it in some detail. On page 4 we are told that the force between two poles of strength m and m' is expressed by the formula $F = \frac{1}{\mu}\frac{mm'}{d^2}$ where μ is a factor of proportionality depending on the medium. "The unit pole is defined so as to make $\mu = 1$ for air." On page 5 the field strength H is defined as being equal to the force in dynes which acts on a unit pole placed at the point. Now, although this is not very helpful in defining what is meant by H inside a mass of iron, let us consider its application inside a gaseous or liquid medium of permeability μ comparable with that of iron. We are faced at once with the difficulty that on taking the knitting needle, the pole strength of which we have carefully adjusted to unity in air, and immersing it in the medium, its pole strength will presumably increase. The analogy between the magnetic and the electric charge breaks down here since an electric charge can be transferred without change from one dielectric medium to another. Let us assume, however, that this difficulty is got over in some way and that the magnetic needles retain the same intensity and distribution of magnetisation when immersed in the new medium, then it is evident from the above formula that the force F on each pole will be reduced to $\frac{1}{\mu}$ of its value in air and that the field strength H due to each pole is at any point reduced to $\frac{1}{\mu}$ of its value in air. On page 6, we are told that the lines of force are drawn with such a density that the number per square centimetre is numerically equal to the field strength, so that the number of lines per sq. cm. is reduced in the ratio $1/\mu$ by immersion in the new medium. When we come to induced currents in Chapter X, we read that the E.M.F. induced in a circuit is equal to the rate at which the number of magnetic lines of force passing through the circuit is altering. Now this does not fit in at all with the foregoing, since if we slip an exploring coil off one of the magnets or move the coil in any way in the magnetic field we shall find that the same E.M.F. is induced in it when immersed in the medium of permeability μ as in the air, always assuming, as is necessary, that the magnets maintain a constant intensity of magnetisation. If the author had omitted the μ in the fundamental equation and confined himself expressly to air he would have been numerically correct—but only numerically—in his statement of the law of induction of E.M.F., as we shall see in a moment. On page 121 it is pointed out that the induced E.M.F. is increased in the ratio 1 to μ by inserting an iron core in the solenoid. "The number of lines of force per cm^2 must consequently be increased in the ratio 1 to μ. The number of lines of force per cm^2 is called the *magnetic induction* in the iron and is always denoted by B." "Magnetic induction has not the same dimensions as magnetic field intensity. . . . Hence $B = H + 4\pi l$." Here is a pretty muddle. If B and H have different dimensions one dare not write this last equation; what dimensions has I, those of B or those of H? This equation $B = H + 4\pi I$ belongs to that school which maintains that B and H have the same dimensions and that $\mu = B/H$ is a numeric. Again is B and H have different dimensions they must not be confused and used indiscriminately even in air, where they are numerically equal. The induction of E.M.F. depends on B and not on H, and even in a vacuum one must carefully discriminate between the flux density B upon which depends the induction of E.M.F., and the magnetic force H which presumably produces B and upon which depends the force on a unit pole. Much might be said on this subject but this is not the place to say it.

G. W. O. H.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Symbolical Algebra.

To the Editor, E.W. & W.E.

Sir,—In my recently completed series of articles on "Mathematics for Wireless Amateurs" (p. 413, July number, 1927), I wrote "The symbol '*j*' is very widely employed in alternating current analysis, but there is a divergence of opinion as to its essential character and occasionally discussions arise as to the legitimacy of certain applications of it, or as to the interpretations of expressions in which it plays a part." The article on this subject in your last number and the Editorial comments thereon certainly bear out this quotation in a very gratifying manner. Like the Irishman in the story, I am going to assume that this is not a "proivate foight," and that anyone can join in. In fact, I should find it difficult not to, for I think I can claim to have contributed somewhat to the popularising of the term "vector operator" and the ideas associated therewith.

Actually a variety of interpretations, or at least shades of interpretation, can be placed upon "*j*," and one's individual choice will be largely a matter of temperament. I personally favour the simple "rotation through 90 degrees" definition on which I based my earliest book on "Alternating Currents and Transients" and the corresponding sections of the series of articles referred to above. It is clear, self-consistent, and sufficient, and Mr. Ratcliffe is quite mistaken in assuming (as he appears to do) that the exponential form for the sine and cosine depends on the alternative algebraic definition $j = \sqrt{-1}$. (If he will pay me the compliment of glancing through the July, 1927, instalment of the above-mentioned articles he will see what I mean by this.)

It is quite clear that a self-consistent system can be based on the formal algebraic definition $j = \sqrt{-1}$ (though the criticism in the May Editorial is very sound and must, I should think, have shaken Mr. Radcliffe somewhat), but any such proceeding would fairly be described as reactionary, for the present tendencies in mathematics are all the other way. The vogue of purely formal definitions and operations is passing. As Professor Whitehead has pointed out, a symbol that is not clearly defined is no more than a blot on paper. By a clear definition he means one that is easily comprehended, and that, at least, can be claimed for the rotation definition of "*j*."

F. M. Colebrook.

Teddington.

Design of Choke Coils and Transformers.

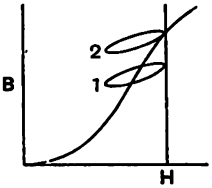
To the Editor, E.W. & W.E.

Sir,—Your Editorial in the February number of *E.W. & W.E.* has just come to my notice. I wish to call attention to a slight error in Fig. 3. The minor loop in this figure has an impossible location if produced according to the description in the text. The right-hand tip of a minor loop can never extend beyond the boundary of the normal induction curve except as noted below.

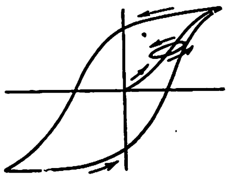
This loop should be located as indicated by position 2 instead of position 1, Fig. (*a*), where the H value for the upper tip of the minor loop corresponds to $H_{dc} + \frac{H}{2}$.

The only method of obtaining a minor loop as indicated in your Fig. 3 is by going through a cycle indicated by Fig. (*b*).

This is a minor matter, but this type of error appears every once in a while in literature, and I thought it desirable to call the error to your attention in order that, in your magazine at least, it will not occur again.



(a)

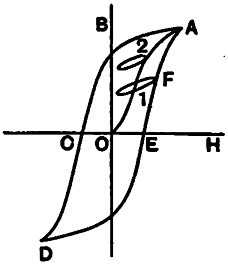


(b)

Thomas Spooner.

East Pittsburgh, Pa.

[Note.—In the Editorial of our February number, we dealt with the design of choke coils which carry a direct current and we referred to the work of Mr. Thomas Spooner, of the Westinghouse Electric and Manufacturing Company on this subject. Mr. Spooner has drawn our attention to a slight error in Fig. 3 of the article. In this figure the small loop was shown with its centre on the direct-current magnetisation curve as in (1) of the figure accompanying this note. As a matter of fact, if one starts at O with a piece of annealed iron which has never been magnetised, and applies a steadily increasing magnetising force, the relation between B and H is somewhat as shown by the curve OA; if now one halts at a point on this curve and superposes a small alternating current, the resulting loop will be as shown at (2) and not as shown at (1); a little consideration will show that this must be so. In order to obtain the loop (1) it would be necessary to take the iron round the major loop $ACDEF$; then by halting at F and superposing the alternating current one might obtain loop (1).—Ed.]



Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

THE STUDY OF SIGNAL FADING. (*E.W. & W.E.*, 5, pp. 267-272, May, 1928.)

Abstract of a paper read by Prof. Appleton before the Wireless Section, I.E.E., on 4th April, dealing with work on the subject of fading carried out at the Peterborough Station of the D.S.I.R.

ÜBER DIE FORTPFLANZUNG ELEKTROMAGNETISCHER WELLEN. (On the propagation of electromagnetic waves.)—H. Benndorf and A. Székely. (*Zeitschr. f. Hochfrequenz*, 31, pp. 43-45, February, 1928.)

Note on a paper of this title by G. J. Elias (this *Zeitschrift*, 27, 66, 1926; these Abstracts, June 1926, p. 381), in which results for the conductivity and dielectric constants of an ionised gas are arrived at rather different from those found by Eccles and Salpeter (and, moreover, afterwards by Lassen). Elias knew of this difference, but attributed the discrepancy, in the case of Salpeter, to an error in his drawing up of the mean value. In view of the fact that Salpeter's formulæ are now used generally as the basis for calculations on the propagation of electric waves in ionised gases, the authors felt it incumbent on them to investigate whether Salpeter's results were really not correct and the exact reason why they were different from those of Elias. As the outcome of their investigation, they found themselves in agreement with Salpeter, and that the discrepancy in the results was due to Elias having employed an incorrect method of counting the ions with a certain free length of path and suffering their last impact within a given interval of time. In the present note a new and simple derivation is given of the formulæ for the conductivity and dielectric constants of an ionised gas, the formulæ so obtained being identical with those deduced by Salpeter by a different method.

The numerical values for the conductivity and dielectric constants resulting from the Salpeter formulæ are calculated and compared with those given by Elias. A table is given showing that the differences between the two are, fortunately, not so very great, so that the inferences drawn by Elias can be considered to hold good in all essentials.

WOODS AND WIRELESS.—B. Rolf. (*Nature*, 121, pp. 539-540, 7th April, 1928.)

A letter referring appreciatively to Mr. Barfield's paper on the attenuation of wireless waves over land (*Jour. Inst. Elect. Eng.*, 66, pp. 204-218, February, 1928).

The writer lays stress upon the fact that a tree cannot possibly be regarded as a pure resistance, except when emission takes place on the resonant frequency of the tree, and since this is generally higher than the frequency of the broadcasting transmitter, the tree acts as a condenser with big losses. In the language of Prof. Sommerfeld's solution, this means that the "numerical distance" is not a positive real number but a complex one.

The damping curve is shown for the particular case when the capacity effect equals the conductivity effect, and explains the remarkable feature that the damping is *negative* for the first 20 or 30 kilometres, though becoming very positive farther away.

The writer states that, in Sweden, "wood" means nothing less than some 40,000 trees per square kilometre, and expresses the belief that a thorough investigation of the attenuation suffered by various wave-lengths would result in better legislation than that decreed by the Washington Conference of 1927 for the broadcasting band to be employed in such densely wooded countries as Sweden.

THE REFLECTING LAYER OF THE UPPER ATMOSPHERE.—G. H. Munro. (*E.W. & W.E.*, 5, pp. 242-244, May, 1928.)

PROPAGATION AROUND THE EARTH.—(*Post Office Elect. Eng. Journ.*, 20, pp. 307-308.)

Examples of the "echo-effect" are shown, which have been observed on the beam installation working between this country and South Africa and India.

RELATION ENTRE LES OSCILLATIONS RÉGULIÈRES DES CHAMPS ELECTRIQUES ET MAGNETIQUES TERRESTRES, ET LES FOYERS SOLAIRES DIAMÉTRAUX (The relation between the regular oscillations of the terrestrial electric and magnetic fields and the diametrical solar foci).—A. Nodon. (*Comptes Rendus*, 186, pp. 942-944, 2nd April, 1928.)

A brief account of observations which appear to show the existence of close relations between the activity of solar diametrical conjugate foci, the variations of terrestrial magnetic and electric fields, and the propagation of radio waves.

THE LORENTZ RECIPROCITY THEOREM FOR ELECTRIC WAVES.—Stuart Ballantine. (*Proc. Inst. Radio Engineers*, April, 1928, V.16, pp. 513-518.)

Under the heading "Review of Current Literature," the writer says that "the following *résumé* of the theorem is based upon a recent article by A. Sommerfeld and will be of interest to radio engineers. The theorem itself has recently been applied to the calculation of the distribution of radiation about a transmitting aerial erected over an imperfect earth by T. L. Eckersley, and to the equivalent problem of the reception of waves arriving from various altitudinal angles, by L. Bouthillon." He also says "The results of the somewhat complicated mathematical analysis are quite amenable to calculation when expressed in simple series and in terms of the so-called 'numerical distance.' An excellent summary of them, with specimen calculations, has been given by Smith-Rose and Barfield (Proc. Wireless Sect., I.E.E., 1, 182, Sept. 1926) which the non-mathematical reader will find especially entertaining and useful."

In the *résumé* the writer states that the results would suggest that communication at short wavelengths between aeroplanes might be feasible at medium distances when communication between ground stations over the same distances might be impossible due to the absorption of the ground wave: and that another practical consequence of these calculations, which was pointed out by Eckersley, is the advantage for ground communication of increasing the height of short-wave antennæ.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

THE EARTH'S ELECTRIC CHARGE.—W. F. G. Swann. (*Journ. A.I.E.E.*, 47, pp. 209-210, March, 1928.)

Our earth is not a neutral body, but is coated with a layer of negative electricity of such amount that, at the surface, there is an electrical potential gradient of the order of 150 volts per metre. This potential gradient diminishes with altitude until, at a height of 10 kilometres, it becomes insignificant compared with its value at the surface. The potential gradient, and so the negative charge on the earth's surface, goes through fairly regular variations throughout the day and throughout the year, variations amounting to 50 per cent. or more of its value. Although the atmosphere is only a very feeble conductor of electricity, this small conductivity, nevertheless, is sufficient to ensure that 90 per cent. of the earth's charge would disappear in 10 minutes if there were no means of replenishing the loss. The nature of this replenishment is the greatest of the outstanding problems of atmospheric electricity.

The author discusses the difficulties attending the explanation of the earth's charge as due to electrons shot into our earth from the sun. He then refers to an entirely different theory according to which a very slow but continual death of positive electricity occurs as a result of the earth's rotation, leaving a surplus of negative sufficient to provide for the atmospheric electric current. It has been possible to incorporate this idea of a slow death of electric charge as a result of the earth's rotation with a consistent scheme of electrodynamics, the rotation at the same time providing an explanation for that other mystery, the earth's magnetic field.

PROPERTIES OF CIRCUITS.

ÜBER STROMVERHÄLTNISSE IN EINEM INDUKTIONSFREIEN WIDERSTAND, DER PARALLEL ZU EINEM SCHWINGUNGSKRIES GESCHALTET IST (On the current relations in an inductance-free resistance, connected in parallel with an oscillatory circuit).—D. Doborzynski. (*Zeitschr. f. Hochfrequenz.*, 31, pp. 15-17, January, 1928.)

A formula is deduced for the amplitude of the sinusoidal alternating current in a resistance, connected in parallel with an oscillatory circuit. It follows that the condition for this amplitude to be a maximum leads to the determination of the resonance capacity of the whole oscillatory circuit. The value of this capacity is entirely independent of the value of the resistance.

ÜBER ANODENGLEICHRICHTUNG (On anode rectification).—M. von Ardenne. (*Zeitschr. f. Hochfrequenz.*, 31, p. 51, February, 1928.)

Supplementing an earlier paper of the same title (*Zeitschr. f. Hochfrequenz.*, March, 1927, these Abstracts, July, 1927, p. 443), the author here investigates the sensitivity of anode rectification in relation to the value and nature of the anode resistance, on the supposition that, for the high-frequency to which adjustment is to be made, this resistance is short-circuited by the capacities in parallel and is very small compared with its value for low-frequency. This case is of importance for the determination of the rectifier effect in multiple amplifiers. It is found that the sensitivity is a maximum when valves with small "Durchgriff" (1μ) and high ohmic resistance are employed.

TRANSMISSION.

FREQUENZDURCHGANG BEI MODULIERTEN FREMDGESTEUERTEN SENDERN MIT MEHREREN GEKOPPELTEN SCHWINGKREISEN (FREQUENZKURVEN) (Frequency variation in modulated externally controlled transmitters with several coupled oscillatory circuits (frequency curves).—P. v. Handel. (*Telefunken-Zeitung*, 9, pp. 53–63, January, 1928.)

A paper calculating the percentage modulation of the antenna current in dependence upon the modulation frequency in a three-cascade transmitter modulated in the second stage. The third stage is assumed to consist of three oscillatory circuits: the primary and secondary circuits and the antenna, the constants of which are supposed known. The calculation is carried out in the following steps:

(1) Frequency relation in a single circuit connected to an oscillatory valve.

(2) Frequency relation in a circuit on which a 100 per cent. modulated high frequency tension is superimposed (antenna coupled inductively).

(3) Frequency relation in the secondary circuit.

(4) Frequency relation in the primary circuit to which a secondary circuit is coupled.

(5) Total frequency relation in a three-cascade transmitter modulated in the second stage.

ÜBER DEN VERLUSTWIDERSTAND BEI LEITUNG VON HOCHFREQUENTEM WECHSELSTROM DURCH ERDE (On the resistance loss when alternating current of high frequency is conducted through the earth).—R. Mayer. (*Telefunken-Zeitung*, 9, pp. 63–68, January, 1928.)

This subject is of importance for radio in connection with the earthing of high-power stations. In determining the losses that occur when alternating currents are conducted through the earth three kinds of loss are differentiated:

(1) Propagation loss due to current concentration in the neighbourhood of metal earths. This loss is identical for direct and alternating current.

(2) Current displacement loss for the free currents through the earth.

(3) Induced losses.

The subject has been treated fairly thoroughly theoretically, though there are important gaps experimentally, especially as concerns "induced losses."

(*Cf. Zeitschr. f. Hochfrequenz*, March, 1927, p. 71; these Abstracts, July, 1927, p. 444.)

STUDY OF MODULATION IN WIRELESS TELEPHONY.—S. Chiba. (*Journ. Inst. Elect. Eng. of Japan*, No. 474, pp. 53–69.)

The character of the modulation in some commonly employed systems is studied by means of the Braun tube. It is found that in the constant-current method, the stop condenser used in the ordinary oscillator circuit has considerable influence on the character of the modulation. Tests are also made on other methods of modulation, such as the grid control and the detuning, and an example of the characteristic given by a magnetic modulator is also described.

Ordinary grid control systems are more or less of the oscillation control type, which sometimes gives rise to serious distortion. The author tested a grid control method using a modulator which at the same time absorbs the high frequency power from the oscillation circuit. This system shows no distortion over the wide range of the modulator grid voltage and the circuit is easily adjusted to attain the distortionless condition. Further advantages are that it is found to be adapted to A.C. filament heating and is also suitable as the transmitter of duplex wireless telephony. A sensitive relay controlled by speech currents is used to open or short-circuit the grid bias battery of the modulator, which in turn starts or stops the oscillation.

THE POWER IN A MODULATED OSCILLATION.—E. Howard Robinson. (*E.W. & W.E.*, 5, pp. 252–254, May, 1928.)

DIE ELEKTRISCHEN EIGENSCHAFTEN DER RUNDFUNKSENDER-VORVERSTÄRKER IM HINBLICK AUF IHRE AKUSTISCHEN QUALITÄTEN (The electrical properties of broadcast transmitter preliminary amplifiers with a view to their acoustical qualities).—H. Rukop. (*Telefunken-Zeitung*, 9, pp. 10–32, January, 1928.)

A paper from the Telefunken laboratories presented before a meeting of the Association of German Electrical Engineers at Kiel, July, 1927.

After surveying the development of the low-frequency amplifier, consideration is made successively of: note frequency amplifiers with resistance coupling, amplifier output and grid transformers, circuit-arrangements for amplification reduction both automatic and by stages, and lastly, broadcast transmitter preliminary amplifiers in practice.

VACUUM TUBES AS OSCILLATION GENERATORS.—D. C. Prince and F. B. Vogdes. (*General Electric Review*, 31, 2 and 3, pp. 97 and 147 respectively, February and March, 1928.)

The third and fourth parts of a serial article on valve oscillators. Part III discusses the design of the simpler valve circuits, and Part IV special considerations bearing on the design and operation of oscillating circuits.

RECEPTION.

ÜBER UNVERZERRTE LEISTUNGSABGABE DURCH ELEKTRONENRÖHREN (On undistorted reproduction with valves).—A. Forstmann. (*Zeitschr. f. Hochfrequenz.*, 31, pp. 45-50, February, 1928.)

The relation for the degree of efficiency of the valve as power amplifier is given, also the optimum load resistance and the useful effect in power amplification are determined. Further, the relations for optimum load, "Durchgriff" (1μ), and driving potentials are set out when distortion (both linear and non-linear) is absent.

DIE FERNBEDIENUNG VON FUNKSEMPFANGSANLAGEN (Attending to radio receiving installations from a distance).—A. Ristow. (*Zeitschr. f. Hochfrequenz.*, 31, pp. 52-53, February, 1928.)

Description of an arrangement for switching on and off and tuning receivers which are not able to be set up in the service room, the chief merit of the arrangement being the economy in special *personnel*. In order not partly to defeat this object by going to the expense of special leads, use is made of the telephone wires presumed already to connect the service room and that containing the installation.

The arrangement is shown diagrammatically on the next page.

RETRO-ACTION IN AMPLIFIERS.—H. A. Thomas. (*E.W. & W.E.*, 5, pp. 245-251, May, 1928.)

THE CAUSES AND PREVENTION OF ACTUAL AND INCIPIENT L.F. OSCILLATION.—W. I. G. Page. (*Wireless World*, 22, pp. 439-444, 25th April, 1928.)

DISCUSSIONS ON THE DISTORTIONLESS RECEPTION OF A MODULATED WAVE AND ITS RELATION TO SELECTIVITY.—F. K. Vreeland. (*Proc. Inst. Radio Engineers*, April, 1928, V. 16, pp. 494-497.)

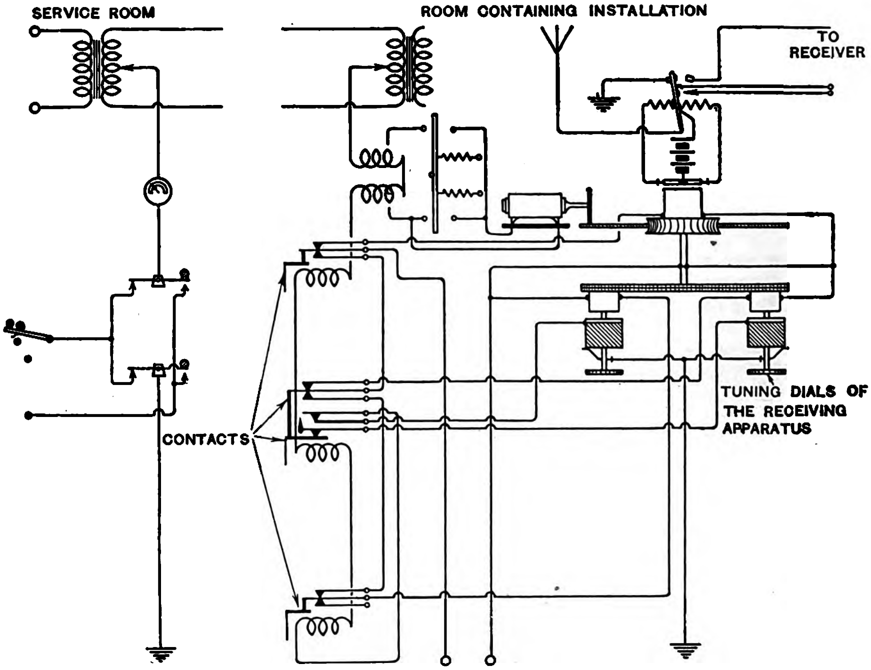
A short discussion on Dr. Vreeland's paper, which was published in the March number of the *Proc. Inst. Radio Engineers*, and was summarised in these abstracts May, 1928, p. 286.

VALVES AND THERMIONICS.

APPLICATIONS NOUVELLES DES LAMPES À QUATRE ELECTRODES (New applications of four-electrode valves).—B. Decaux. (*L'Onde Electrique*, 7, pp. 119-124, March, 1928.)

Some Past Developments and Future Possibilities in very High Voltage Vacuum Tubes.—W. D. Coolidge. (*General Electric Review*, 31, pp. 184-185, April, 1928.)

Rejuvenating Rectifying Valves. (*Wireless World*, 22, p. 445, 25th April, 1928.)


SERVICE ROOM
ROOM CONTAINING INSTALLATION
TO RECEIVER
CONTACTS
TUNING DIALS OF THE RECEIVING APPARATUS

The Effect of Residual Gas in a Valve.—A. P. Castellain. (*Wireless World*, 22, pp. 385-388, 11th April, 1928.)

Einige Überlegungen zur physikalischen Bedeutung der Glühelektronen-Emission (Some considerations on the physical significance of incandescent electron emission).—A. v. Hippel. (*Zeitschr. f. Physik*, 46, pp. 716-724.)

The theory is given for regarding incandescent electron emission as a question of temperature ionisation through atomic impact.

Relations of Field-Currents to Thermionic-Currents.—R. A. Millikan and C. C. Lauritsen. (*Proc. Nat. Acad. Sciences*, 14, pp. 45-49.)

In 1925 Millikan and Eyring first developed experimentally the quantitative laws governing the extraction of electrons from metals by fields alone, *i.e.*, the laws of "field-currents." They proved that the electrons constituting these field-currents are not identical with thermions, as had hitherto been assumed.

The present paper shows, however, that at high enough temperatures the fields do extract electrons which share in the energy of thermal agitation (thermions) as well as those which do not: in other words, at high enough temperatures the two effects are not independent. A general equation is obtained which seems to embrace all the facts of thermionic-currents and field-currents combined. The new results in this paper may be stated thus: The application of an external field is equivalent to increasing the temperature of the electrons within the metal.

Development of a New Power Amplifier Valve.—C. R. Hanna, L. Sutherlin, and C. B. Upp. (*Proc. Inst. Radio Engineers*, April, 1928, V. 16, pp. 462-475.)

This paper, from the Westinghouse Research Laboratory, is summarised as follows:—

A general rule for determining the best operating point and load impedance for any power amplifier, when anode voltage and dissipation limits must both be considered, is derived.

The effect of varying the voltage factor in a given sized valve, by changing the grid structure, is also considered with voltage and heating kept within safe limits.

The process of determining the desired characteristics for a given application is illustrated by describing the development of a new power-valve, Radiotron UX-250.

The writer states that the high output of this valve is the result of several features, the most important four of which he enumerates. He concludes that the output of this valve is about as great as may be obtained from a receiving valve of practical structure without requiring greater grid swing or operating at excessive anode voltage or dissipation.

SOME CHARACTERISTICS AND APPLICATIONS OF FOUR-ELECTRODE TUBES.—J. C. Warner. (*Proc. Inst. Radio Engineers*, April, 1928, V. 16, pp. 424-446.)

This paper, from the Research Laboratory of the G.E.C., is summarised as follows :—

Four-electrode valves may be classified by their designs and uses as "screen-grid," "space-charge-grid," and "double function" valves.

In the screen-grid valve the inner grid is the control-electrode and the outer or screen-grid is kept at a fixed potential. The capacity between plate and control-grid is thereby reduced to an almost negligible value. A second result of the screen-grid is a large increase in amplification factor and plate resistance without reduction of mutual conductance. This permits high amplification in connection with high impedance coupling circuits, without undesired regeneration or oscillation. The screen-grid principle has been applied to transmitting as well as to receiving valves.

Characteristics of these valves are given in detail.

In the space-charge-grid valve, the outer grid is the control electrode and the inner grid is maintained at a fixed potential. The purpose of the inner grid is to reduce the effect of the space-charge around the filament and thereby to reduce the plate resistance of the valve. The space-charge-grid valve performs the same functions as ordinary three-electrode valves, but in general has higher mutual conductance than a three-electrode valve of similar design.

Several double-function valves and circuits are described in which both grids act as control electrodes, or in which one grid acts as control electrode and the other as a combination space-charge-grid and control or output electrode. These circuits are sometimes useful, but are subject to certain definite limitations.

The writer concludes: "The degree of general usefulness of the various four-electrode valves and circuits may perhaps be expressed by saying that the space-charge-grid valve performs the same kind of functions as the three-electrode valve but at lower plate voltages or with somewhat higher amplification; the double-function circuits, while often very interesting in themselves, accomplish with one valve what can often be done almost as simply, as effectively, and sometimes less expensively with two three-electrode valves; but the screen-grid valve not only permits a degree of radio-frequency amplification much greater than can be obtained with a three-electrode valve, but also eliminates the feed-back which is so often an unwanted function of the three-electrode valve."

DIRECTIONAL WIRELESS.

NOTE ON A SPECIAL DIAL FOR TIME-PIECES TO BE USED WITH ROTATING WIRELESS OR OTHER BEACONS.—R. L. Smith-Rose. (*Journ. Scien. Instr.*, 5, pp. 93–96, March, 1928.)

The author states that in the near future it is probable that the rotating beacon transmitter will find wide application as a means of obtaining wireless bearings for navigation purposes. This paper describes some specially designed "compass-card" dials for watches and chronographs used in connection with such beacons.

LE RADIOCOMPAS ET LA NAVIGATION AÉRIENNE (The radio compass and aerial navigation).—P. Franck. (*L'Onde Electrique*, 7, pp. 109–118, March, 1928.)

A lecture given to the S.A.T.S.F., 10th January, 1928.

The writer enumerates the several advantages, for aerial navigation, that a *direct-reading* radio direction-finder would have over the magnetic compass, but points out how many problems are involved, and have yet to be solved, before a really satisfactory instrument is perfected.

MEASUREMENTS AND STANDARDS.

MEASUREMENT OF FREQUENCY.—S. Jimbo. (*Journ. Inst. Elect. Eng. of Japan*, No. 475, pp. 132–151, February, 1928.)

The contents of the paper are as follows:

(1) Method of measurement of frequency.
  (A) Absolute method.
  (B) Relative method.
(2) Standard frequency oscillator.
  (A) Clock-controlled oscillator.
  (B) Tuning-fork oscillator.
  (C) Quartz oscillator.
  (D) Valve oscillator.
(3) Resonator.
  (A) Electric resonator.
    (*a*) Frequency bridge.
    (*b*) Wavemeter.
  (B) Mechanical resonator.
    (*a*) Fork type resonator.
    (*b*) Sonometer type resonator.
    (*c*) Quartz resonator.

The author recommends the stroboscopic and phonic motor method as the most precise for the absolute measurement of frequency; with it he has obtained an accuracy of nearly 0.001 per cent. The clock-controlled oscillator is also favourably considered, and it is suggested that its operation can be theoretically explained by the "Ziehen" phenomenon and the equivalent electric circuit.

The fundamental equation for the frequency of the elastic wave in the mechanical vibrator is given and several factors affecting the frequency of the tuning-fork oscillator are enumerated and explained. A monochord oscillator is put forward. Resonant sharpness is discussed. A comprehensive bibliography is appended.

A NEW UNIVERSAL LONG-WAVE RADIO INTENSITY MEASURING SET.—J. Hollingworth. (*Journ. Sci. Instr.*, 5, pp. 1–9, January, 1928.)

A paper pointing out that the existing long-wave measuring apparatus is found not sufficiently refined for the more complicated observations now required in the study of the polarisation of radio waves, and giving a detailed description of new apparatus for the purpose, which is primarily designed to measure in rapid succession the E.M.Fs in two coils oriented in different directions from the arriving signal, and the phase angle between these two E.M.Fs.

A SHORT SURVEY OF SOME METHODS OF RADIO SIGNAL MEASUREMENT.—K. Sreenivasan. (*E.W. & W.E.*, 5, pp. 273–278, May, 1928.)

Concluding part of a paper begun in the April issue.

THE DEMONSTRATION OF A NEW PRECISION WAVEMETER CONDENSER.—W. H. F. Griffiths. (*E.W. & W.E.*, 5, pp. 278–279, May, 1928.)

THE MEASUREMENT OF CHOKE COIL INDUCTANCE.—C. A. Wright and F. T. Bowditch. (*Proc. Inst. Radio Engineers*, 16, pp. 373–384, March, 1928.)

Description of an investigation that emphasises the following facts:

(1) The inductance of the choke coil depends upon the degree to which its core is magnetically saturated because of direct current flowing through the winding of a choke coil.

(2) With a given direct current flowing through the winding of a choke coil, the inductance varies to a marked extent with the magnitude of the alternating current flowing through the winding. Methods of measurement which do not take into account or measure the magnitude of the alternating current are, therefore, unreliable.

(3) The inductance for given conditions may be determined from the saturation curve of the coil. It is determined by the average slope of the saturation curve over the range within which the current varies.

Three modifications of the ammeter-voltmeter method of measuring inductance are given.

THE ESTABLISHMENT OF FORMULÆ FOR THE SELF-INDUCTANCE OF SINGLE-TURN CIRCUITS OF VARIOUS SHAPES.—R. G. Allen. (*E.W. & W.E.*, 5, pp. 259–263, May, 1928.)

A BRIDGE FOR THE MEASUREMENT OF INDUCTANCE AND CAPACITY.—G. Zickner. (*E.W. & W.E.*, 5, pp. 280-282, May, 1928.)

METHODS, FORMULAS, AND TABLES FOR THE CALCULATION OF ANTENNA CAPACITY.—F. W. Grover. (*Scientific Papers of the Bureau of Standards*, No. 568.)

The capacity of an antenna is evaluated by assuming a certain charge upon it from which the resulting potential is calculated. As the law of the distribution of the charge is not known, difficulties are encountered. While the values obtained by this method and the published values for the same antennæ by the inductance methods differ, the author shows that if appropriate inductance formulæ are employed, the two methods will agree.

Formulæ are given for the common types of single and multiple wire antennæ, together with tables of constants, also tables of capacities of both horizontal and vertical single-wire antennæ and horizontal two-wire antennæ.

COIL CALCULATIONS.—(*Wireless World*, 22, pp. 394-395, 11th April, 1928.)

Useful design data for 2,000 and 3,000 microhenry coils.

DIELECTRIC LOSSES IN SINGLE LAYER COILS AT RADIO FREQUENCIES.—W. Jackson. (*E.W. & W.E.*, 5, pp. 255-258, May, 1928.)

THE HARMONIC COMPARISON OF RADIO-FREQUENCIES BY THE CATHODE-RAY OSCILLOGRAPH.—T. S. Rangachari. (*E.W. & W.E.*, 5, pp. 264-266, May, 1928.)

ON THE TESTING OF AUDIO-FREQUENCY TRANSFORMERS BY MEANS OF THE CATHODE-RAY OSCILLOGRAPH.—M. Kobayashi. (*Journ. Inst. Elect. Eng. of Japan*, No. 475, pp. 152-159, February, 1928.)

The cathode-ray oscillograph is very satisfactorily applied to the determination of the characteristics of apparatus which is to be used over a wide range of frequency. Here, in the application to the testing of the audio-frequency transformer, impedance and voltage frequency characteristics are obtained vectorially from the elliptic figure on the oscillograph, various points to be noticed being enumerated.

A DIRECT-CAPACITY BRIDGE FOR VACUUM-TUBE MEASUREMENTS.—Lincoln Walsh. (*Proc. Inst. Radio Engineers*, April, 1928, V.16, pp. 482-486.)

A direct-capacity bridge is described which permits the measurement at a single setting of a capacity associated with other capacities in a system having more than two terminals, such as the grid-plate capacity of a valve.

Two forms of the bridge are described. By making one connection, the standard form of capacity bridge already in use in many laboratories may be converted into a direct-capacity bridge.

The recommendation is made that valve inter-element capacities be specified as direct capacities. Suggestions are made for other uses of the direct-capacity bridge in the laboratory.

MEASUREMENT OF VACUUM-TUBE CAPACITIES BY A TRANSFORMER BALANCE.—H. A. Wheeler. (*Proc. Inst. Radio Engineers*, April, 1928, V.16, pp. 476-481.)

A complete, portable equipment is described for the measurement of the direct capacities of valves in laboratory or factory testing. The valve capacity is compared with a standard variable condenser by means of a transformer-balance (Neutrodyne) circuit, whose balance is independent of the frequency (about 1,500 kc. being preferred). Designs are proposed for the standard condenser and the transformer, and suggestions are made for the further improvement of this equipment. The writer states that the total errors obtained should be very small, within 1 per cent. or 0.1 $\mu\mu$F, and that they can be reduced further if required.

A BRIDGE METHOD FOR THE MEASUREMENT OF INTER-ELECTRODE ADMITTANCE IN VACUUM TUBES.—E. T. Hoch. (*Proc. Inst. Radio Engineers*, April, 1928, V.16, pp. 487-493.)

This paper, from the Bell Telephone Laboratories, gives a description of the Colpitts-Campbell bridge as applied specifically to the measurement of direct admittances in vacuum tubes. Data on several vacuum tubes are given.

The writer concludes that the tests indicate that the method is applicable at radio frequencies although, on account of the very small quantities to be measured, great refinement is necessary in the physical construction of the bridge and accessory apparatus.

SUBSIDIARY APPARATUS AND MATERIALS.

GENERATOR FOR AUDIO CURRENTS OF ADJUSTABLE FREQUENCY WITH PIEZO-ELECTRIC STABILISATION.—A. Hund. (*Scientific Papers of the Bureau of Standards*, No. 569.)

A beat-frequency generator for producing audio currents which are practically sinusoidal is described. The frequency is adjustable and stabilised by means of a piezo-electric quartz disk and can be directly read off on a scale. The piezo-electric control makes it possible to reset the calibration for the frequency, for almost any B voltage on the valves producing the two high-frequency currents which beat with each other. The resetting can be carried on without any standard by means of the filament rheostat common to both oscillator valves. The slow visible vibrations on the meter for the anode current of the piezo-electric oscillator are utilised for the resetting of the scale. A thermostatic control is provided for very accurate work. Two filter detector circuits are described for obtaining audio currents of a good wave shape and keeping any high-frequency currents away from the load branch. A specially designed power amplifier is also mentioned.

LOUD-SPEAKERS OF HIGH EFFICIENCY AND LOAD CAPACITY.—C. R. Hanna. (*Journ. Amer. Inst. Elect. Eng.*, 47, pp. 253-257, April, 1928.)

Abridgment of a paper presented at the winter convention of the A.I.E.E., New York, February, 1928.

The design of high-quality horn-type loud-speakers with moving coil drivers is considered, and the efficiency and maximum output capacity obtainable from this type of loud-speaker are calculated. Methods of providing loud capacity greater than that possible with a single loud-speaker are described.

ÜBER BAU UND ANWENDUNG VON GROSSLAUTSPRECHERN (Design and application of large loud-speakers).—F. Trendelenburg. (*E.T.Z.*, 48, pp. 1685-1691.)

Mathematical explanation is given of the phenomena involved when mechanical energy is transformed into acoustical energy. The ideal sound emitting surface is a sphere, but approximations to it are cones, circular diaphragms and large square surfaces. Characteristics of paper and metal horns are given, indicating their varying sensitiveness depending upon the sound frequency. It is claimed that for large sound energies, such as are required by public address speakers, the condenser type with an emitting sheet 20 × 20 in. gives best results with a minimum of distortion within a range of 50 to 8,000 cycles. Tests made in the open country showed that such a hornless sheet speaker permitted the spoken word to be clearly understood over a distance of half a mile.

MOTIONAL IMPEDANCE CHARACTERISTICS OF A LOUD-SPEAKER WITH A VERY SMALL HORN.—S. Nakai. (*Journ. Inst. Elect. Eng. of Japan*, No. 474, pp. 26-37.)

The effect of the small horn upon the motional impedance, which is the measure of the velocity of the actuating element, is found to be limited to the narrow range of frequencies near the resonant frequency of the horn. When this resonant frequency coincides with that of the moving element, the addition of horn changes the shape of the frequency characteristics. It is concluded that a small horn contributes very little to the improvement of the frequency response.

A GERMAN H.T. MAINS UNIT WITH GLOW DISCHARGE RECTIFIER.—(*E.W. & W.E.*, 5, p. 251, May, 1928.)

EIN GLÜHKATHODENOSZILLOGRAPH FÜR VAKUUMAUFNAHMEN (An incandescent cathode oscillograph for vacuum recording).—W. Rogowski and K. Baumgart. (*Archiv für Elektrotechnik*, 19, pp. 521-526, 15th March, 1928.)

Description of a new oscillograph with incandescent cathode which has several advantages over the cold cathode instrument devised previously—except that it is less easy to handle. Specimen oscillograms obtained within the tube are shown.

ÜBER DIE VERWENDUNG DER NEGATIVEN LADUNG DER KATHODENSTRAHLEN ALS SCHREIBMITTEL IM KATHODENOSZILLOGRAPHEN (On the employment of the negative charge of the cathode beam as the recording means in the cathode oscillograph).—P. Selényi. (*Zeitschr. f. Physik*, 47, pp. 895-897, March, 1928.)

Description of a new principle in recording, employing the electric charge of the cathode beam, which is caught on an insulating plate, sprinkled over with an electroscopic powder to render the curve traced out visible. It is expected that a recording velocity of over 30 km./sec. will be attainable with this method.

NOTES ON THE DESIGN OF RADIO INSULATORS.—T. Walmsley. (*Proc. Inst. Radio Engineers*, 16, pp. 361-372, March, 1928.)

The writer states that there seems to be no general appreciation of the fact that better results can usually be obtained by proportioning insulators correctly than by increasing the quantity of material used. In fact, increased thickness of a dielectric, having a high dielectric constant, frequently causes a reduction in the breakdown voltage of the insulator.

Design problems are considered under the headings: quality of material, shape and arrangement of material, surface leakage, dome insulators, and sheds.

LIQUIDS AS INSULATORS.—F. M. Clark. (*General Electric Review*, 31, pp. 174-183, April, 1928.)

THE INVERTED VACUUM TUBE, A VOLTAGE-REDUCING POWER AMPLIFIER.—F. E. Terman. (*Proc. Inst. Radio Engineers*, April, 1928, V.16, pp. 447-461.)

By interchanging the functions of the grid and plate of the usual vacuum tube, a voltage-reducing power amplifier is obtained. The usual vacuum tube acts as a voltage-increasing power amplifier.

The static curves of the inverted vacuum tube are similar in form to the corresponding curves of the ordinary vacuum tube, and the theory of the inverted vacuum tube is analogous in all respects to the usual vacuum-tube theory, the only difference being reduction instead of amplification of voltage.

It is relatively simple to construct an inverted vacuum tube with wide clearances between plate and the rest of the tube, so that potentials of hundreds of thousands of volts can be applied to the plate, while the effect of this high voltage stepped down in almost any desired ratio is obtained in a low-potential circuit.

The writer considers various practical applications of the inverted vacuum tube and comes to the conclusion that its usefulness lies principally in oscillograph work, and in the measurement of A.C. and D.C. voltages of any magnitude without the consumption of power from the unknown potential.

STATIONS : DESIGN AND OPERATION.

SEAFORTH RADIO STATION.—W. M. Osborn. (*Post Office Elect. Eng. Journal*, 21, pp. 65-70, April, 1928.)

An illustrated description of this coast station near Liverpool, where, last August, the spark system of transmission was replaced by that of interrupted continuous waves. Following this successful installation, arrangements are in hand for the general adoption of the valve transmitter at all other coast radio stations in place of the existing spark transmitters.

THE "EMPIRADIO" BEAM STATIONS.—(*Post Office Elect. Eng. Journal*, 21, pp. 55-65, April, 1928.)

An illustrated account of the group of stations in this country operating on the beam system for communication with Canada, South Africa, India, and Australia.

BROADCAST CONTROL OPERATION.—Carl Dreher. (*Proc. Inst. Radio Engineers*, April, 1928, V.16, pp. 498-512.)

Mr. Dreher, of the National Broadcasting Company, New York City, summarises his paper as follows : This paper is limited to a consideration of the audio-frequency elements of a broadcast control system. A two-studio electrically interlocked plant suitable for network operation is described. The methods of specifying and measuring telephonic energy levels, arranging low impedance (as 500-ohm) and bridging apparatus, equalising lines, and maintaining the audio energy within permissible limits by means of amplifying and attenuating units, are described in connection with the specifications of the plant. The co-ordinative and regulative functions of the technical staff of a broadcasting system, the relations of engineering and studio *personnel*, and typical precautions against breaks in programme-continuity are then discussed.

GENERAL PHYSICAL ARTICLES.

QUELQUES MODES PARTICULIERS DE VIBRATION DES QUARTZ PIEZO-ELECTRIQUES (Some particular modes of vibration of piezo-electric quartz plates).—R. Jouaust. (*L'Onde Electrique*, 7, pp. 125-128, March, 1928.)

The writer here supplements his lecture to the S.A.T.S.F., in May of last year, on the employment of piezo-electric quartz as a frequency standard (*O.E.*, Nov. and Dec., 1927), with an account of new modes of vibration (flexural and torsional), which have been produced since ; as described by Giebe and Schiebe in the *Zeitschrift für Hochfrequenz*. of July, 1927, and by Harrison in the *Proc. Inst. Rad. Eng.* of December, 1927. With these more complicated deformations, lower frequencies can be obtained than when only transverse or longitudinal deformations are utilised, and thus the field over which quartz can be employed in radio measurements becomes extended.

PIEZOELEKTRISCHE ERREGUNG VON DEHNUNGS- BIEGUNGS- UND DRILLUNGSSCHWINGUNGEN BEI QUARZSTÄBEN (Piezo-electric excitation of extension, flexural and torsional oscillations in quartz rods).—E. Giebe and A. Scheibe. (*Zeitschr. f. Physik*, 46, pp. 607-652, January, 1928.)

MECHANISCHE SCHWINGUNGEN PIEZOELEKTRISCH ANGEREGTER QUARZE (Mechanical oscillations of piezo-electrically excited quartz).—R. Wachsmuth and H. Auer. (*Zeitschr. f. Physik*, 47, pp. 323-329, February, 1928.)

BEEINFLUSSUNG DER DIELEKTRIZITÄTSKONSTANTEN DURCH ELEKTROSTATISCHE FELDER (The influencing of dielectric constants by electrostatic fields).—F. Kautzsch. (*Physikalische Zeitschrift*, 29, pp. 105-117.)

EIN VERSUCH DER ABLEITUNG DES MAXWELLSCHEN VERTEILUNGSGESETZES AUF THERMODYNAMISCHEM WEGE (An attempt to deduce Maxwell's law of distribution by thermodynamical means).—A. Schükaren. (*Physikalische Zeitschrift*, 29, pp. 181-182.)

ÉTUDE EXPÉRIMENTALE DES DÉFORMATIONS ET DES CHANGEMENTS DE PROPRIÉTÉS OPTIQUES DU QUARTZ SOUS L'INFLUENCE DU CHAMP ELECTRIQUE (Experimental investigation of the deformations and change in optical properties of quartz under the influence of an electric field).—M. Ny Tsi Ze. (*Journal de Physique*, 9, pp. 13-37, January, 1928.)

THÉORIE ÉLECTRO-OPTIQUE DU QUARTZ (Electro-optical theory of quartz).—R. de Mallemann. (*Comptes Rendus*, 186, pp. 853-855, 26th March, 1928.)

Zur Feldtheorie von Elektrizität und Gravitation (On the field theory of electricity and gravitation).—L. Infeld. (*Physikalische Zeitschrift*, 29, pp. 145-147.)

Theory of the Magnetic Nature of Gravity and Newton's Laws.—C. L. Sagui. (*Physical Review*, 31, p. 715, April, 1928.)

Abstract of a paper presented at the New York meeting of the American Physical Society, February, 1928.

As in a gravitational field, the magnetic quanta of two electromagnetic fields spacially superposed, with one lagging behind the other, react elastically upon each other in such a way that those advancing meet those returning. The latter are pushed farther away and the former recede, and different magnetic densities result. An electron results as an assembly of a large number of elementary electromagnetic fields (energy-wave) with a gravitational atmosphere (gravity-wave). The repelling forces are explained and radiation connected with the oscillation of electrons between attractive and repelling forces.

Bibliography on Piezo-electricity.—W. G. Cady. (*Proc. Inst. Radio Engineers*, April, 1928, V.16, pp. 521-535.)

A general bibliography on Piezo-electricity and its applications. The writer hopes that it is fairly complete to the beginning of 1928.

Part I deals with Books and Periodical Literature, and includes over 200 references, with a Cross Index. Part II deals with Patents, the title of each patent being followed by a parenthetical note pointing out the distinguishing features from the point of view of piezo-electricity, without attempting to indicate the full scope of the invention.

Modes of Vibration in Piezo-electric Crystals.—A. Crossley. (*Proc. Inst. Radio Engineers*, April, 1928, V.16, pp. 416-423.)

The paper, from the Naval Research Laboratory, Anacostia, D.C., is summarised as follows:—

The presence of nodes and antinodes on the surface of oscillating quartz crystals has been discovered. The symmetrical arrangement of these nodal points permits a study of the modes of vibration in the crystal plate and the use of the following formulæ for determination of the velocity of sound waves through quartz, and of Young's modulus.

$$V = F2T \quad e = V^2D$$

where V is the velocity, F the frequency, T the thickness of the plate, e Young's modulus, and D the density.

The value obtained for V was 5,733 metres per second, while 8.785×10^{11} c.g.s. units represents Young's modulus for plane parallel to X-axis dimension.

MISCELLANEOUS.

An Instrument for Measuring very small Displacement or Motion and its various applications.—J. Obata. (*Journ. Inst. Elect. Eng. of Japan*, No. 474, pp. 38-52.)

Description of the construction and application of the "Ultramicrometer," a new instrument for measuring small displacement or motion, utilising a generating valve circuit. The displacement or motion to be measured is made to produce either a change in the capacity in the circuit or a change in the eddy-current loss, resulting in a corresponding change in the anode current, which is measured with a galvanometer or Duddell oscillograph.

Decreasing Radio Congestion.—R. D. Duncan, Jr. (*Electrical World*, 91, pp. 195-197.)

An article directing attention to the advantages and possibilities that would accompany the use of single side-band (and carrier) transmission in space radio broadcasting as compared with double side-band transmission now employed.

Fernsteurung durch Tonfrequenz (Remote control by means of note frequency).—F. J. Dommerque. (*Elekt. Nachr. Technik*, 5, p. 129, March, 1928.)

Über elektrischer Felder in der Umgebung lebender Wesen (On electric fields in the neighbourhood of living beings).—F. Sauerbruch and W. Schumann. (*Zeitschr. f. Techn. Physik*, 9, pp. 96-98, March, 1928.)

Account of the graphical recording of varying electric distance effects produced by the physiological process of muscle stretching and contraction.

Scientific Wiring.—W. B. Medlam. (*Wireless World*, 22, pp. 449-452, 25th April, 1928.)

A new viewpoint with regard to stray coupling caused by wiring.

The Cable Wireless Merger.—F. J. Brown. (*Wireless World*, 22, pp. 389-392, 11th April, 1928.)

Symbolical Algebra.—J. A. Ratcliffe. (*E.W. & W.E.*, 5, pp. 239-242, May, 1928.)

The International Radiotelegraph Conference of Washington, 1927.—W. D. Terrell. (*Proc. Inst. Radio Engineers*, April, 1928, V.16, pp. 409-415.)

This account of the purposes and results of the Conference is written by the Chief of Radio Division, U.S. Department of Commerce.

D. E. H.

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPAGADO DE ONDOJ.

La Reflekta Tavolo de la Supra Atmosfero.—G. H. Munro.

La prelego traktas pri mezuradoj faritaj en Nova Zelando en Decembro, 1925a pri 600-metra sparka stacio de distanco 300-mejla. La mezuradoj estis faritaj je horoj antaŭ kaj ĉirkaŭ sunleviĝo. Oni donas tabelon montrantan la efekton de sunlumo ĉe signalforteco, kaj de l'alteco de sunlumo (laŭ mejloj) ĉe loko meze inter stacioj je diversaj horoj antaŭ sunleviĝo ĉe la riceva stacio. Oni deduktas altecon de 57 mejloj kiel la malsupran limon por la Tavolo Heaviside.

Aldonaĵo pritraktas la kalkuladon laŭ kio la suno brilas super loko sur la tera surfaco je difinita horo antaŭ sunleviĝo ĉe tiu loko, la latitudo estinte sciita. Oni donas kaj ilustras ekzemplon, la ekzemplo pritraktita estante por somermezo en la Suda Duonsfero.

La Studado pri Signalo-velkado.

Resumo de prelego legita de Prof. E. V. Appleton, F.R.S., ĉe la Senfadena Sekcio, Institucio de Elektraj Inĝenieroj, Londono, je la 4a Aprilo, 1928a.

La prelego estas rakonto pri la laborado de la Peterborough Radio-Esplorada Stacio de la Brita Registara Fako de Scienca & Industria Esplorado. Ĝi unue diskutas la specon de la problemo de signalaj variadoj, kaj poste pritraktas metodon evoluigitan de l'aŭtoro determini la karakterizojn de la malsuprenvenanta radistrio, per observado ĉe la riceva stacio, dum la sendita ondolongo estas malrapide variigita ĉe la sendilo. La teorio de la metodo estas plene diskutita kaj eksperimentaj detaloj kaj rezultoj donitaj.

La dua duono de la prelego pritraktas observadojn faritajn je l'okazo de la suna eklipso de 29a Junio, 1927a, kiam serio de observadoj ĉi tiuspecaj estis farita, kune kun observadoj pri porta ondo de konstanta amplitudo kaj frekvenco.

Oni donas kaj komparas kurvojn de la diversaj rezultoj, montrantajn la starigon de noktaj efektoj dum la eklipso.

Raporto de la diskutado, kiu sekvis la legadon de la prelego, estas ankaŭ donita.

PROPRECOJ DE CIRKVITOJ.

Reakcio Ĉe Amplifikatoroj.—H. A. Thomas.

En la enkonduka sekcio, la aŭtoro aludas al la malfacileco analizi reakciajn efektojn. Li poste diskutas tipojn de reakcio, kaj intenca kaj akcidenta, kaj kondukas al detala matematika ekzamenado de la reakcia efekto. Esprimoj estas derivitaj por la *norma amplifa koeficiento*, la *reakcia koeficiento*, kaj la *fina amplifa koeficiento*, k.t.p. La argumento estas bone ilustrita per vektoroj montrantaj la efekton de kelkaj reakcioj kaj ilia kombiniĝo. La maksimuma valoro de amplifado estas pritraktita kaj la kondiĉoj por stabileco kaj malstabileco ekzamenitaj.

Grafika ekzemplo de la reakcia efekto estas poste donita, ilustrita per vektoroj por kelkaj diversaj ekzemploj.

La Starigo de Formularo por la Mem-indukteco de unu-Turnaj Cirkvitoj de Diversaj Formoj.—R. G. Allen.

Komencante per fundamentaj supozoj, la aŭtoro skizas la teorian evoluigon de l'esprimo por la indukteco de unusola ronda turno.

La rezonado estas poste etendita al la ekzemplo de kvadrata bobeno, rektangula bobeno, bobeno kun formo de egallatera triangulo kun unu turno de fadeno, kaj de bobeno sesangulforma.

Redakcia artikolo super la ĉefliteroj de Prof. Howe ankaŭ pritraktas ĉitium temon, aludante al prelego de Bashenoff, ĉe la Institucio de Elektraj Inĝenieroj, donanta oportunajn esprimojn por unu bobeno laŭ formo de rondo, oktangulo, kvinangulo, kvadrato, triangulo, k.c.

Dielektrikaj Perdoj en Unutavolaj Bobenoj je Radio-frekvencoj.—W. Jackson.

La artikolo priskribas eksperimentojn, dum kiuj altfrekvencaj rezistecaj komparoj estis faritaj inter norma desegno de bobeno (aerinterspacigita kaj vindita per minimumo de solida dielektriko), kaj bobenoj kun la samaj dimensioj vinditaj ĉirkaŭ tuboj de ebonito, mikarto, tektono, imita ledo, paksolino, kaj kartono. Oni priskribas la metodon vindi la norman bobenon kaj ilustras la finitan bobenon. Altfrekvencaj rezistecaj mezuradoj estis faritaj laŭ la rezisteca variada metodo, kaj rezultaj kurvoj estas donitaj por la diversaj materialoj komparitaj kun la norma bobeno. La efekto de malseketeco en la tubo estas ankaŭ montrita pri la ekzemplo de l'kartona tubo.

Variado kun frekvenco de l'aldonita rezisteco kaŭze de dielektrika perdo estas ankaŭ pritraktita teorie kaj eksperimente, rezultaj kurvoj estante montritaj. La prelego finiĝas per komparode rezultoj de la norma bobeno kun teoriaj valoroj, kurvoj estante donitaj por la kalkulitaj valoroj kaj por observitaj valoroj kun kaj sen korekto por mem-kapacito.

SENDADO.

La Potenco en Modulita Oscilado.—E. Howard Robinson.

Oni atentigas, ke se la ĉefa frekvenca tensio (t.e. porta) ne estas de konstanta amplitudo sed estas variigita harmonike, laŭ alia frekvenco, la kutima alternkurenta kalkulado de potenco ne aplikas.

La kutima esprimo por modulita porta ondo estas poste donita kaj estas uzita por derivi esprimon por potenco. La argumento estas etendita al la pluaj ekzemploj de du flankstrioj sen portanto kaj de unu flankstrio sole.

La diversaj rezultoj por Efika Valoro (tensio aŭ kurento), Potenco, kaj Proporcio de Maksimuma Pinto je Efika Valoro, estas resumita en tabelo.

Oni atentigas, ke eĉ je 100-procenta modulado en ordinara radio-telefona sendilo nur triono de la tuta altfrekvenca potenco estas sendita laŭ formo de utila modula komponero.

RICEVADO.

Germana Alt-tensia Ĉeftuba unuo kun Ardmalŝarga Rektifikatoro.

Artikolo super la ĉefliteroj de Prof. Howe pritraktanta germanan valvon, la " Anotron," ŝulditan al D-ro. Georgo Seibt. Ci tio estas arda malŝarga valvo kun katodo supre kaj du anodoj malsupre, kaj oni pretendas pri ĝi konstantajn karakterizojn. Cirkvita diagramo por plenonda rektifado, glatigado kaj konektado por diversaj alt-tensiaj valoroj kaj por krada potencialo estas montrita, kun sekciaj bildoj de l' " Anotron " valvo.

MEZUROJ KAJ NORMOJ.

La Harmonika Komparo de Radio-frekvencoj per la Katod-radia Oscilografo.—T. S. Rangachari.

Post aludo al la malfacilaĵoj interpreti la ciferojn de Lissajon laŭ la altaj proporcioj de frekvenco, la aŭtoro aludas al aliaj metodoj. Unu, ŝuldita al Kipping (*Western Electric Company*), donas malaltfrekvencan rondon kun altfrekvencaj randoj. La rotacianta radistria metodo, ŝuldita al D-ro. D. W. Dye, estas poste aludita, aparte utiligante aranĝojn por doni malgrandan rondan movadon al la katoda radistrio je radio-frekvenco, dum la pligranda ronda aŭ elipsa movado okazas je aŭd-frekvenco.

Cirkvitaj aranĝoj por ĉi tiu celo estas priskribitaj, la aŭtoro aparte pritraktante unu aranĝon, kiu, oni trovis, estas tre oportuna. La rezultanta modelo havas la formon de rondo aŭ elipso kun maŝoj, kaj ekzemploj de modeloj efektive obtenitaj estas donitaj.

Mallonga Priskribo de Kelkaj Metodoj de Radio-signala Mezurado.—K. Sreenivasan.

Finita el la antaŭa numero.

La nuna parto revuas la metodon de Baumler, okupita en Germanujo dum 1923-4a pri la ricevado de Tuckerton. Oni poste traktas pri la metodo de Austin, donante detalojn pri la ĝeneralaj aranĝoj kaj pri la elpensaĵo uzita por mezuri telefonan kurenton. La metodo de la Marconi-Kompanio (priskribita de Round, Eckersley, Tremellen, kaj Lunnon) estas poste diskutita, ĉi tiu estinte uzita ĉe la vasta ekspedicio al kaj de Aŭstralio. La Metodo de la Nacia Fizika Laborejo (ŝuldita al J. Hollingworth) estas laste priskribita, kun cirkvitaj diagramoj de la ĝenerala skemo, antenaj kaj agordaj cirkvitoj, altfrekvenca amplifikatoro, k.t.p.

Aparato, kiu plenumas ĉi tiun priskribon, estas instalita ĉe Bangalore kaj uzita por observadoj faritaj koncerne la forteco de Madras-Radio.

HELPA APARATO.

La Demonstracio de Nova Precizeca Kondensatoro.—W. H. F. Griffiths.

La artikolo aludas al la demonstracio (donita ĉe la Januara Ekspozicio de la Fizika Societo de Londono) de la nova modelo de precizeca kondensatoro priskribita de l'aŭtoro en *E.W. & W.E.* de Januaro kaj Februaro, 1928a.

La demonstracio permesis la faron de 5-procenta dislokigo de la tuta dielektrika interspaco, kaj kurvoj estas donitaj montrantaj komparojn inter ĉi-tiu kondensatoro kaj kondensatoro de la ordinara paralel-interspaca modelo.

La efekto de intersekcia skrenado en la nova kondensatoro estas ankaŭ montrita.

Ponto por la Mezurado de Indukteco kaj Kapacito.—D-ro. G. Zickner.

Oni donas priskribon de ponta cirkvito, kiu estas uzebla por induktecoj de 10 ĝis 100,000 μH, kaj, per simpla komutatoro, por kapacitoj de 500 $\mu\mu$F ĝis ĉirkaŭ 1 μF.

La principoj de la ponto estas diskutitaj kaj diagramoj donitaj pri ĝia konekta metodo por ĉiu celo, dum funkciigaj kaj aliaj notoj estas ankaŭ donitaj.

DIVERSAĴOJ.

Resumoj kaj Aludoj.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

Simbola Algebro.—J. A. Ratcliffe.

La artikolo traktas pri la operatoro $j=\sqrt{-1}$, kun celo pruvi, ke la ordinaraj reguloj de algebro estas aplikebla al ĝi. La signifo de " imaga numero" estas pritraktita kaj aplikita al ĝenerala kompleksa numero, kiel ekzemple $x+jy$. La geometria signifo de tia esprimo kaj de plua multipliko de ĝi per j estas poste diskutita. La ekzemplo de simpla sinusa ondo estas poste konsiderita, kondukante al la kompleksa esprimo

$$\text{kos } pt + j \text{ sin } pt = e^{jpt}$$

kaj la korekta traktado kaj interpretado de ĝi estas montrita.

Redakcia artikolo kritikas kelkajn el la opinioj esprimitaj en la ĉi-supra artikolo, kaj atentigas pri kelkaj el la malfacilaĵoj asociigitaj kun la esprimo $j = \sqrt{-1}$.

LIBRO-RECENZOJ.

Recenzoj estas donitaj, super la ĉefliteroj de Prof. Howe, de la jenaj verkoj :—

" Amatora Radio-Vortareto en Kvin Lingvoj," eldonita en Prago.

" Der Sprechende Film " (La Parolanta Filmo), de Dénes von Mihály, eldonita en Berlin.

Some Recent Patents.

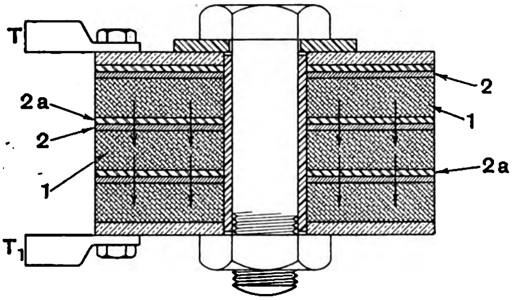
The following abstracts are prepared with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each.

METAL RECTIFIERS.

(*Convention date* (*U.S.A.*), 19*th January*, 1927. *No.* 283901.)

A circular copper blank 1 is heated in an atmosphere of oxygen so as to produce a thin surface layer 2 of red cuprous oxide. The oxidised disc has an asymmetrical resistance, current passing more readily from the oxide to the metal than in the reverse direction. Difficulty is however experienced when using the combination as a rectifier, in making good electrical contact with the oxide layer.

To overcome this drawback a part of the oxide layer is reduced electrolytically. The surface layer is first pierced and contact made with the pure copper. The combination is then immersed in an electrolytic bath containing a saturated solution of potassium fluoride through which an electric current is passed. This reduces part of the oxide, so that the treated blank 1 consists of the mother copper, faced with a thin layer of oxide 2, the latter being coated in turn with a fine desposit 2a of oxide reduced to the pure metal, thus giving a good electrical contact on both sides of the rectifying layer. A number of treated blanks are then bolted together to form a rectifying unit, which is provided with terminals T, T_1 as shown in the figure.

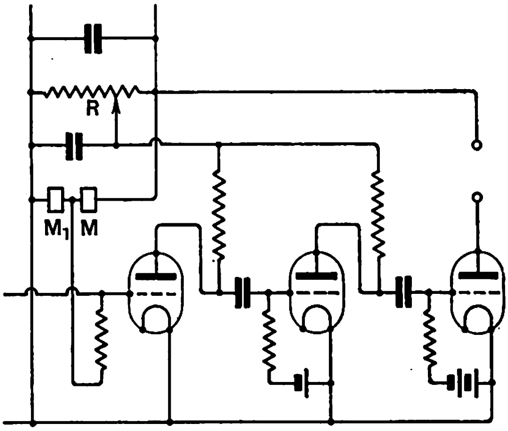


Patent issued to Metropolitan Vickers Electrical Co., Ltd.

STABILISING AMPLIFIERS.

(*Application date*, 20*th January*, 1927. *No.* 285,229.)

In order to counterbalance any tendency to instability caused by a common impedance in the H.T. supply to a multistage amplifier, additional impedances are inserted tending to set up reaction effects in opposition to the undesired back-coupling. As shown in the case of an amplifying set drawing H.T. supply from the mains, two impedances M, M_1, the first consisting of a large capacity of 1 microfarad and the second of a high resistance up to 1 megohm, are shunted in series across the potentiometer resistance R. The mid-point is connected to the grid of one of the valves, preferably the first, so that a fraction of the total H.T. voltage is applied to that valve.



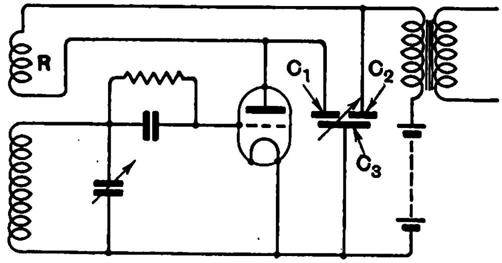
By regulating the resistance M_1, the applied grid-voltage, derived from the H.T. supply, can be adjusted to oppose the inherent back-coupling, both in phase and value, and so ensure stability.

Patent issued to Igranic Electric Co.

CONSTANT-CAPACITY COUPLING.

(*Application date*, 15*th November*, 1927. *No.* 286578.)

The coupling condenser comprises two separate sets of fixed vanes C_1, C_2, and movable vanes C_3, the shape of the plates being such that as the capacity, say, between the vanes C_3 and C_2 increases, that between C_3 and C_1 decreases by a corresponding amount. The two ends of the reaction coil R are connected to the fixed vanes C_1, C_2, so that whilst the value of the high frequency current flowing in the raction coil can be suitably controlled, the overall shunt capacity from plate to filament remains constant.



This permits the degree of reaction to be varied without affecting the external capacity of the valve, and consequently without de-tuning the grid circuit. The three-plate condenser also provides a constant-capacity path to by-pass high-frequency components away from the low-frequency stages of the amplifier.

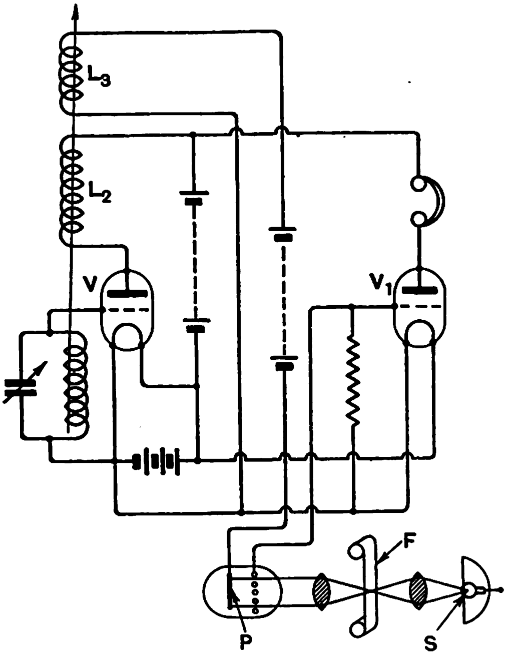
Patent issued to The Igranic Electric Co., Ltd.

PHOTO-ELECTRIC MODULATION.

(*Convention date* (*U.S.A.*), 16*th February*, 1926. *No.* 266288.)

In television or picture-transmission systems the usual procedure is to sub-divide the picture into a number of isolated points and to transmit signal impulses corresponding to the consecutive changes in light intensity of these points. This normally involves the amplification by thermionic valves of the changes in current output from a photo-electric cell subject to a light-ray of varying intensity, the amplified current then being utilised to modulate a separate radio-frequency source or carrier-wave. In such a system, a sequence of uniform light intensity would not give rise to current variation unless a suitable analysing frequency is employed to cut up the otherwise "blank" interval.

The present method of modulation ensures that a dark stretch in the transmitted picture is indicated not by a "blank" interval but by a continuous weak signal, whilst bright stretches of picture are transmitted as stronger signals. The valve oscillator V generates a continuous carrier-wave. Coupled to the output coil L_2 is a coil L_3 inserted in series with a photo-electric cell P in the grid of an amplifying valve V_1.



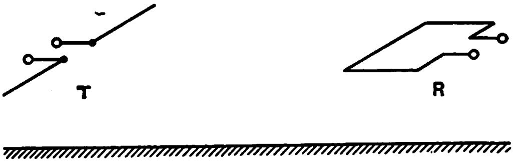
Light from a source S passes through a photographic film F on to the photo-electric cell and so increases or diminishes the effective impedance of the input circuit L_3, P. The output from the amplifier V_1 accordingly varies in proportion to the light and shade effects existing on the film F or other picture to be transmitted.

Patent issued to The Dubilier Condenser Co.

SHORT-WAVE SIGNALLING.

(*Convention date* (*Germany*), 29*th October*, 1926. *No.* 279823.)

Apart from temporary disturbances due to magnetic storms, serious difficulty in the reception of short-wave signals arises from fading and from static impulses which are known to have a predominantly vertical polarisation, *i.e.*, the electrical vector is directed at right-angles to the earth's surface. In order to minimise both these factors an horizontal loop aerial R is used for reception, so that vertically-polarised static is cut out. The transmitter T consists of a dipole oscillator mounted so that it can be set at any desired angle, in order to compensate for fading due to changes of polarisation in the wave-front during reflection at the Heaviside layer. This ensures that the incoming signals are horizontally polarised when they impinge on the frame aerial R, so that they produce a maximum effect on the receiver.



Patent issued to Dr. A. Esau.

TELEVISION SYSTEMS.

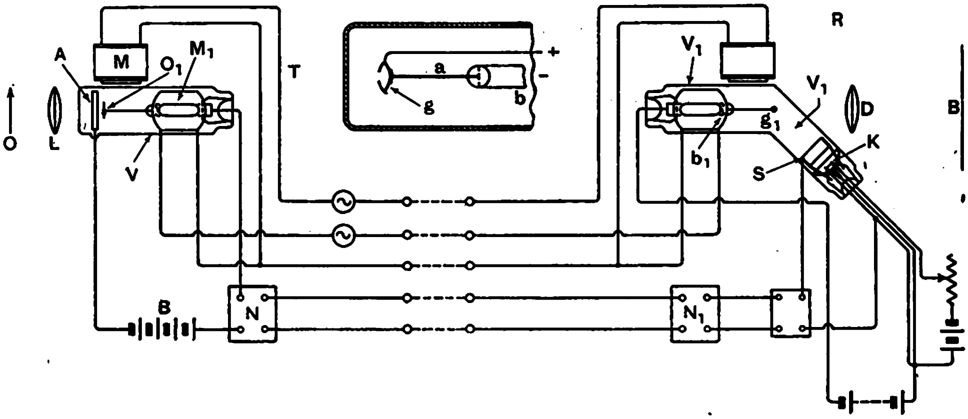
(*Application date*, 24*th December*, 1926. *No.* 287643.)

An image O_1 of the object to be transmitted is projected by a lens L into the interior of a photo-electric cell V, the light-rays passing through a pierced or perforated anode A. The image is then scanned by a light-sensitive point g mounted at the end of a vibrating system comprising two flat springs a, b, joined end to end. The springs are vibrated individually by two external electro-magnets M, M_1, fed by currents having frequencies of 1,000 and 10 cycles per second respectively. The same synchronising currents control a similar vibrating spring system at the receiving end R.

The sensitised point g is connected to the negative and the anode A to the positive pole of a high-tension battery B. The resulting variations of photo-electric current are amplified at N and are then transmitted, either by wire or through the ether, to the receiver where, after passing through an amplifier N_1, they are applied to the grid S of a tube V_1 and so control the emission of electrons from a heated cathode K.

For reception the vibrating spring system a_1,

b_1 is fitted with a fluorescent or luminous point g_1, forming the anode of the thermionic tube V_1. The bombardment of electrons on the sensitised point g_1, as it moves in synchronism with the corresponding point g at the transmitting end, reconstitutes the original image, which is then projected by a lens D on to a viewing-screen B.



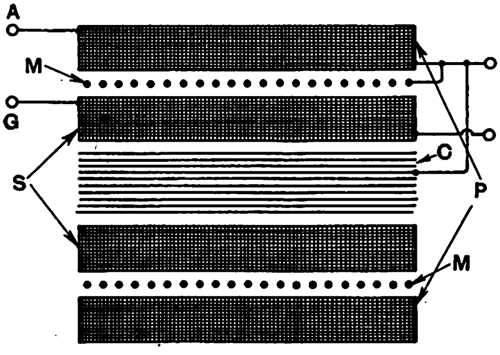
Patent issued to B. Rtcheouloff.

PROTECTING TRANSFORMERS.

(*Application date, 18th October*, 1926. *No.* 287191.)

It is assumed that transformer breakdown is due not to excessive current or mechanical vibration, as is generally assumed, but rather to the effect of electrolytic leakage, whereby current tends to pass through the insulation layers and thus sets up corrosion at the point where it leaves the metal wire. In this connection it is pointed out that a certain amount of moisture is bound to be present during the process of manufacture of the insulating compound. In addition it is impossible to avoid the formation of minute pinholes in the layer protecting the finished wire.

These factors tend to set up a small electrolytic "leakage" current under the pressure of the high-tension voltage across the primary and secondary windings. In the arrangement shown in the figure, the primary winding P is separated from the secondary S by a layer M of thicker-gauge wire, or by a metallic shield, which is connected to the H.T. positive and also to the laminated core C, as shown at the right hand. Any electrolytic leakage which may exist will now leave the high potential level from the metal screen M, which is made sufficiently substantial to withstand the resulting corrosion. The plate and grid terminals are shown at A and G respectively.

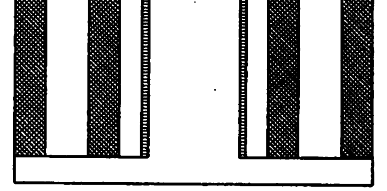


Patent issued to Burndept Wireless, Ltd.

LOUD-SPEAKERS.

(*Application date, 23rd December*, 1926. *No.* 287631.)

Loud-speakers may be divided into two types according as the elastic restraint upon the diaphragm is (*a*) sufficient to ensure that the "natural" frequency of vibration is above the useful acoustic range, or (*b*) so small that the fundamental frequency falls below audibility. In the latter or inertia-controlled type, the weight of the vibratory element becomes an important factor, though when the diaphragm movement takes place in a horizontal plane the effect of weight can be compensated by a restraint at right-angles so that it does not directly affect the line of vibration.



The present invention is intended to compensate for the weight of the vibratory parts in the case where a moving-coil instrument, such as the well-known R.K. speaker, is mounted for vertical operation. As shown in the figure, a saucer-shaped diaphragm *D* is energised by means of a coil *C* located in the air-gap of a magnetic system *M*. The diaphragm is loosely mounted in cotton-wool packing *W* in an annular baffle-board *B*, and is centred by means of a pin *P*.

In addition to the normal output current from the amplifier, the coil *C* is supplied with a direct-current component of such strength that its reaction with the magnetic field exactly counterbalances the weight of the moving system. The emerging sound waves are dispersed radially by a sound-board *S* arranged parallel with the diaphragm *D*.

Patent issued to The British Thomson-Houston Co., Ltd.

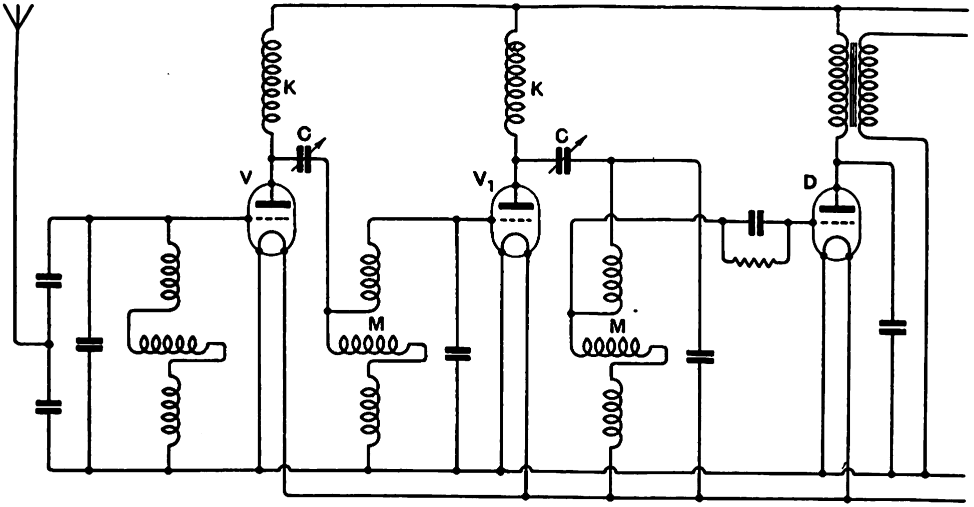
HIGH-FREQUENCY AMPLIFIERS.

(*Application date*, 19*th September*, 1927. *No.* 286991.)

The input circuit, which comprises a potentiometer arrangement of condensers, is tuned by a variometer. Both the stages of valve amplification are tuned by a variometer *M* in series with an adjustable condenser *C*. Stability is ensured by keeping the value of the coupling-condensers below a certain critical point. Under these conditions the inductive reactance in the anode circuit is kept too low to allow self-oscillation to be set up through the valve capacities.

Each of the variometers *M* comprises three coils, the centre one being adjustable relatively to the other two. By a slight readjustment of the condensers *C* the sensitivity of the receiver can be maintained uniform over a wide band of wave-lengths. The tuned couping-circuits *C*, *M* are dissociated from the high-tension supply through choke coils *K*.

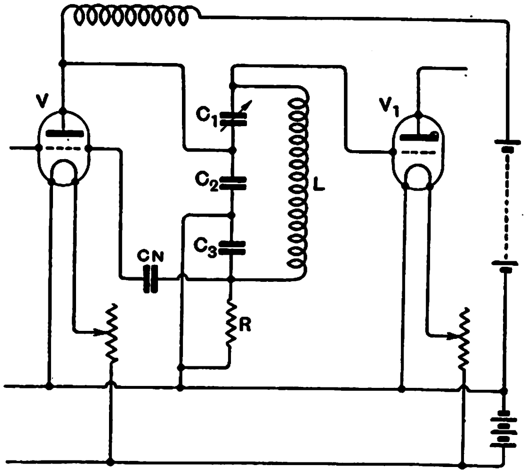
Patent issued to Igranic Electric Co., Ltd.



INTERVALVE COUPLINGS.

(*Application date*, 9*th March*, 1927. *No.* 287312.)

In order to secure a voltage step-up, the capacity in the tuned-anode circuit of the valve *V* consists of three series connected condensers C_1, C_2, C_3, the anode connection being taken to a point between the first two, whilst the common cathode connection goes to a point between the last two, as shown. When the circuit is tuned by means of the condenser C_1, the voltage difference across the terminals of the condensers C_1 and C_2 in series will be greater than that across the variable condenser alone.



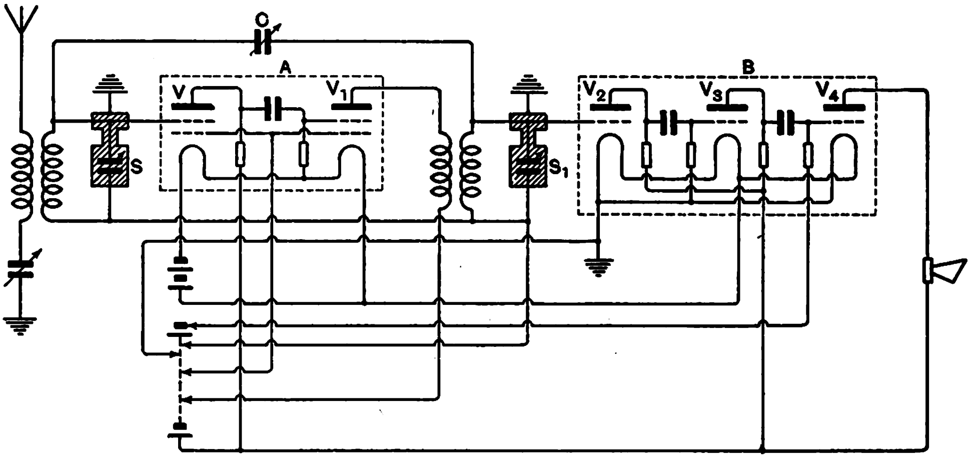
This higher voltage variation is accordingly applied to the input circuit of the next valve V_1. A balancing condenser *CN* minimises inter-electrode capacity coupling, its point of connection to the coil *L* being joined to the common cathode circuit by a high-resistance *R*. Any residual inter-electrode coupling, as the frequency increases, is automatically compensated by the decrease in overall amplification due to the effective shifting of the anode tapping point as the capacity of the tuning condenser C_1 is diminished.

Patent issued to W. J. Brown and Metropolitan Vickers, Ltd.

MULTIPLE-STAGE VALVE SETS.

(*Convention date* (*Germany*), 26*th October*, 1926. *No.* 279843.)

The drawing shows one multiple valve stage *A* comprising two high-frequency four-electrode units V, V_1, followed by a multiple valve *B* comprising a detector V_2, low-frequency amplifier V_3, and power amplifier V_4. The inventor states that such a combination is peculiarly liable to feed-back effects of an obscure nature. Though the causes are difficult to identify, he has discovered that a simple and effective remedy consists in shielding the input condensers and leads of the two separate stages as indicated by the hatched area at S and S_1.



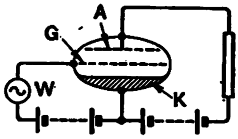
In addition the multiple valves *A* and *B* are also preferable enclosed in earthed metal screening cylinders (not shown). A small condenser *C* provides an adjustable reaction control.

Patent issued to Dr. S. Loewe.

PHOTO-ELECTRIC MODULATORS.

(*Convention date* (*Germany*), 15*th October*, 1926. *No.* 279068.)

The modulation of a carrier-wave by the feeble currents derived from a photo-electric cell offers considerable difficulties, particularly when it is necessary to cover a wide frequency range as in television systems or in the transmission of still-life photographs by line-wire or wireless.



The single-stage photo-electric modulator shown in the figure comprises a light-sensitive cathode *K*, a control grid *G*, and an anode *A* which is perforated so that an incident ray of light can fall directly on to the cathode *K*.

The carrier-wave frequency is applied directly to the photo-electric cell from a separate source *W* connected across the grid and cathode. On exposure to light the carrier-wave is modulated in accordance with the varying intensity of illumination, and the resultant complex current created in the output circuit of the cell can be amplified in any known manner without difficulty.

Patent issued to the Telefunken Co.

EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. V. JULY, 1928. No. 58.

Editorial.

The Equivalent Inductance and Capacity of an Aerial with Inserted Tuning Coil or Condenser.

IN an editorial note in the June issue we drew attention to the fact that the treatment of this subject in Dr. Palmer's recently published "Wireless Principles and Practice" led to results at variance with those which we published in 1917; we also pointed out what it was that caused this difference and showed that the two different methods of solving the problem, if correctly applied, both led to the same correct result.

We might have mentioned that the values which we obtained in 1917 have since been generally accepted and derived in various ways by other writers.*

We refer to the matter again, because the subject is of considerable interest, and as Dr. Palmer attempts in a letter, which we publish in this issue, to justify his result with the aid of some arguments with which we do not agree.

An aerial without any tuning coil or condenser is equivalent to a simple circuit with inductance L_0 and capacity C_0, but since the equivalent values of inductance and capacity change when inductance or capacity is inserted at the foot of the aerial, the values corresponding to the aerial alone can only be determined by adding infinitely small reactances—*i.e.*, either very small inductances or very large capacities. In other words, since the change we make to determine the equivalent values alters the values which we wish to determine, we must only make a very small change if we wish to obtain an accurate result; otherwise we obtain a result which is dependent on the magnitude of the change. This is a case in which the result can be obtained quite simply and accurately by means of the differential calculus, as we showed in our editorial. Of course, one obtains a result by inserting a large inductance, or small capacity, but the result so obtained lies somewhere between the correct result for the aerial when earthed and the correct result for the aerial when loaded with the added inductance or capacity.

Dr. Palmer's statement that we ascribe his erroneous result to his neglecting a certain term is not correct; what he neglects is the fact that this term, "which is by no means negligible, varies as the square of the frequency." It is true that he says that his result is only an approximation. We shall show later how the approximation fits in with the facts.

The equivalent inductance of the aerial

---

* See, for example, J. M. Miller, *Proc. of Inst. of Radio Eng.*, Vol. 7, p. 312, 1919 (equation 17); also August Hund, *loc. cit.*, Vol. 8, p. 426, 1920. The former refers to our 1917 article.

when no tuning coil is inserted is $\frac{hL}{2}$, and as an inductance inserted between it and the earth is increased its equivalent inductance decreases until when a very large inductance is inserted the equivalent inductance of the aerial itself is $\frac{hL}{3}$. If the wavelength is shortened by inserting a condenser the equivalent inductance of the aerial is increased. We shall now set ourselves this question: for what value of the tuning coil or condenser will the equivalent inductance of the aerial be equal to $\frac{hL}{2{\cdot}46}$, the approximate value obtained by Dr. Palmer?

Wavelength Increased by Inserting an Inductance.

Let L_1 and C_1 be the equivalent inductance and capacity of the aerial when an inductance L_x is inserted between it and the earth; then the reactance of the whole equivalent circuit will be given by the formula:—

$$X = \omega\ (L_1 + L_x) - \frac{1}{\omega C_1} \quad \ldots \quad (1)$$

If $\omega_1/2\pi$ is the resonant frequency, then

$$\frac{1}{C_1} = \omega^2{}_1\,(L_1 + L_x)$$

and $$X = \omega_1\,(L_1 + L_x)\left(\frac{\omega^2 - \omega^2{}_1}{\omega\omega_1}\right) \ldots \quad (2)$$

For the rate of change of X with ω we have

$$\frac{dX}{d\omega} = (L_1 + L_x)\left(1 + \frac{\omega^2{}_1}{\omega^2}\right) \quad \ldots \quad (3)$$

Near resonance $\omega = \omega_1$ and

$$\frac{dX}{d\omega} = 2(L_1 + L_x) \quad \ldots \quad (4)$$

Turning now to the actual aerial with its tuning coil, we have the reactance of the aerial $-\sqrt{\frac{L}{C}}$ cotan $\omega h\sqrt{LC}$ in series with the reactance ωL_x of the tuning coil—that is, a total reactance of

$$X = \omega L_x - \sqrt{\frac{L}{C}}\,\text{cotan}\,\omega h\sqrt{LC} \quad \ldots \quad (5)$$

Differentiating this we have

$$\frac{dX}{d\omega} = L_x + \sqrt{\frac{L}{C}}\,h\sqrt{LC}\,\frac{1}{\sin^2 \omega h\sqrt{LC}} \quad (6)$$

At resonance $\omega = \omega_1$; we shall assume that the value of L_x is such that $\omega_1 = a\omega_0$ where $\omega_0/2\pi$ is the resonant frequency of the aerial alone, *i.e.*, when $L_x = 0$.

Since $\omega_0 h\sqrt{LC} = \pi/2$, we have at resonance

$$\frac{dX}{d\omega} = L_x + \frac{hL}{\sin^2 a\pi/2} \quad \ldots \quad \ldots \quad (7)$$

Equating this to the value found above for the equivalent circuit we have

$$2(L_1 + L_x) = L_x + \frac{hL}{\sin^2 a\pi/2},$$

therefore

$$L_1 = \frac{hL}{2\sin^2 a\pi/2} - \frac{L_x}{2} \quad \ldots \quad (8)$$

but since at resonance the total reactance (equation 5) must be zero

$$L_x = \frac{1}{a\omega_0}\sqrt{\frac{L}{C}}\,\text{cotan}\,a\omega_0 h\sqrt{LC}$$
$$= \frac{hL}{a\pi/2}\,\text{cotan}\,a\pi/2 \ldots \quad \ldots \quad (9)$$

and on substituting this value for L_x in (8) we have

$$L_1 = \frac{hL}{2}\left(\frac{1}{\sin^2 a\pi/2} - \frac{\text{cotan}\,a\pi/2}{a\pi/2}\right) \quad (10)$$

This gives the equivalent inductance of the aerial for any value of a, where a is the ratio of the frequency with the tuning coil L_x to that without the tuning coil, and L is the inductance per unit length of the aerial.

If $a = 1$ we have $L_1 = \frac{hL}{2}$ for the equivalent inductance of the plain aerial without any inserted inductance. This is what we have called L_0.

As a approaches zero, the quantity in brackets approaches $\frac{2}{3}$*, so that $L_1 = \frac{hL}{3}$ if a very large inductance is inserted, always assuming that the aerial may be regarded as a transmission line with a fixed value of inductance and capacity per unit length—a very doubtful assumption.

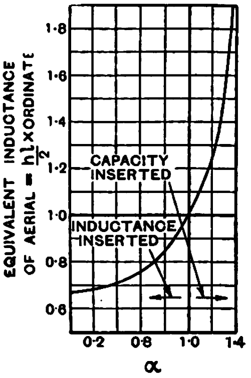
---

* We are indebted to Dr. B. Hague for evaluating this limit.

For other values of α the quantity in brackets has been calculated and the values are as follows :—

$\alpha =$	1.0	0.9	0.8	⅔	0.5	⅓	0
	1.0	0.913	0.847	0.782	0.727	0.694	0.667

These are plotted in the accompanying graph.



$$\alpha = \frac{\text{frequency with tuning coil or condenser}}{\text{fundamental frequency}}.$$

Wavelength Reduced by Inserting a Condenser.

If the natural frequency of the aerial be increased by inserting a condenser C_x between it and the earth, the reactance of the equivalent circuit will be given by the formula

$$X = \omega L_1 - \frac{1}{\omega . \dfrac{C_1 C_x}{C_1 + C_x}} \quad .. \quad (11)$$

If $\omega_1/2\pi$ is the resonant frequency, then $L_1 = \frac{1}{\omega_1{}^2 C'}$ where C' is put for the resultant capacity $\frac{C_1 C_x}{C_1 + C_x}$;

$$\therefore \quad X = \frac{1}{\omega_1 C'}\left(\frac{\omega^2 - \omega_1{}^2}{\omega\,\omega_1}\right) \quad .. \quad (12)$$

and $$\frac{dX}{d\omega} = \frac{1}{\omega_1{}^2 C'}\left(1 + \frac{\omega_1{}^2}{\omega^2}\right) \quad .. \quad (13)$$

Near resonance

$$\omega = \omega_1 \text{ and } \frac{dX}{d\omega} = \frac{2}{\omega_1{}^2 C'} = 2L_1 \quad (14)$$

For the reactance of the actual aerial with the condenser inserted between it and the earth we have

$$X = -\frac{1}{\omega C_x} - \sqrt{\frac{L}{C}}\operatorname{cotan} \omega h\sqrt{LC} \quad (15)$$

and therefore

$$\frac{dX}{d\omega} = \frac{1}{\omega^2 C_x} + \sqrt{\frac{L}{C}}\, h\sqrt{LC}\, \frac{1}{\sin^2 \omega h\sqrt{LC}} \quad (16)$$

At resonance $\omega = \omega_1 = \alpha\omega_0$, where

$$\omega_0 h\sqrt{LC} = \pi/2.$$

Hence at resonance

$$\frac{dX}{d\omega} = \frac{1}{\omega_1{}^2 C_x} + \frac{hL}{\sin^2 \alpha\pi/2} \quad .. \quad (17)$$

but since at resonance equation (15) must be zero,

$$\frac{1}{\omega_1 C_x} = -\sqrt{\frac{L}{C}} . \operatorname{cotan} \alpha\pi/2$$

and

$$\frac{dX}{d\omega} = hL\left(\frac{1}{\sin^2 \alpha\pi/2}\right) - \frac{\operatorname{cotan} \alpha\pi/2}{\alpha\pi/2} \quad (18)$$

Comparing this with equation (14) for the equivalent circuit, we find that

$$L_1 = \frac{hL}{2}\left(\frac{1}{\sin^2 \alpha\pi/2} - \frac{\operatorname{cotan} \alpha\pi/2}{\alpha\pi/2}\right) \quad (19)$$

which is, of course, identically the same as the expression found for the case of inserted inductance. α is in this case greater than unity. The quantity in brackets has the following values :

$\alpha =$	1.0	1.2	4/3	1.5
	1.0	1.223	1.608	2.424

These are also plotted on the right-hand side of the graph.

We can now answer the question which we set ourselves, and the answer is as follows : The aerial has an equivalent inductance of $\frac{hL}{2.46}$ when α=0.73 ; that is, when a tuning coil with such an inductance that the frequency of the aerial is reduced to 73 per cent. of its fundamental value is inserted between the aerial and earth, and only then.

When one speaks of the natural frequency of an aerial or of its equivalent inductance and capacity, it is generally assumed that the values referred to are those for the aerial alone, *i.e.*, without inserted inductance and capacity.

It will be obvious that the value $\frac{hL}{2.46}$ has no special merit as an approximation beyond the fact that the corresponding value of the equivalent capacity is simply hC. When $\alpha=0.73$ it will be quite accurate and for other values of α it will be a close enough approximation for most practical purposes when a tuning coil is connected in series with the aerial. It has the advantage in this case of lying roughly halfway between the limiting values $hL/2$ and $hL/3$.

Dr. Palmer's mathematical treatment overlooks the change of the equivalent inductance of the aerial as inductance or capacity is inserted in series with it, and his graph is made to favour his result by confining it to the case of added inductance.

We do not suggest that Dr. Palmer should have gone into the matter in his book in such detail as we have done here, for equation (10) and the accompanying graph have been specially evolved for the purposes of this note and, so far as we know, have not been previously published.

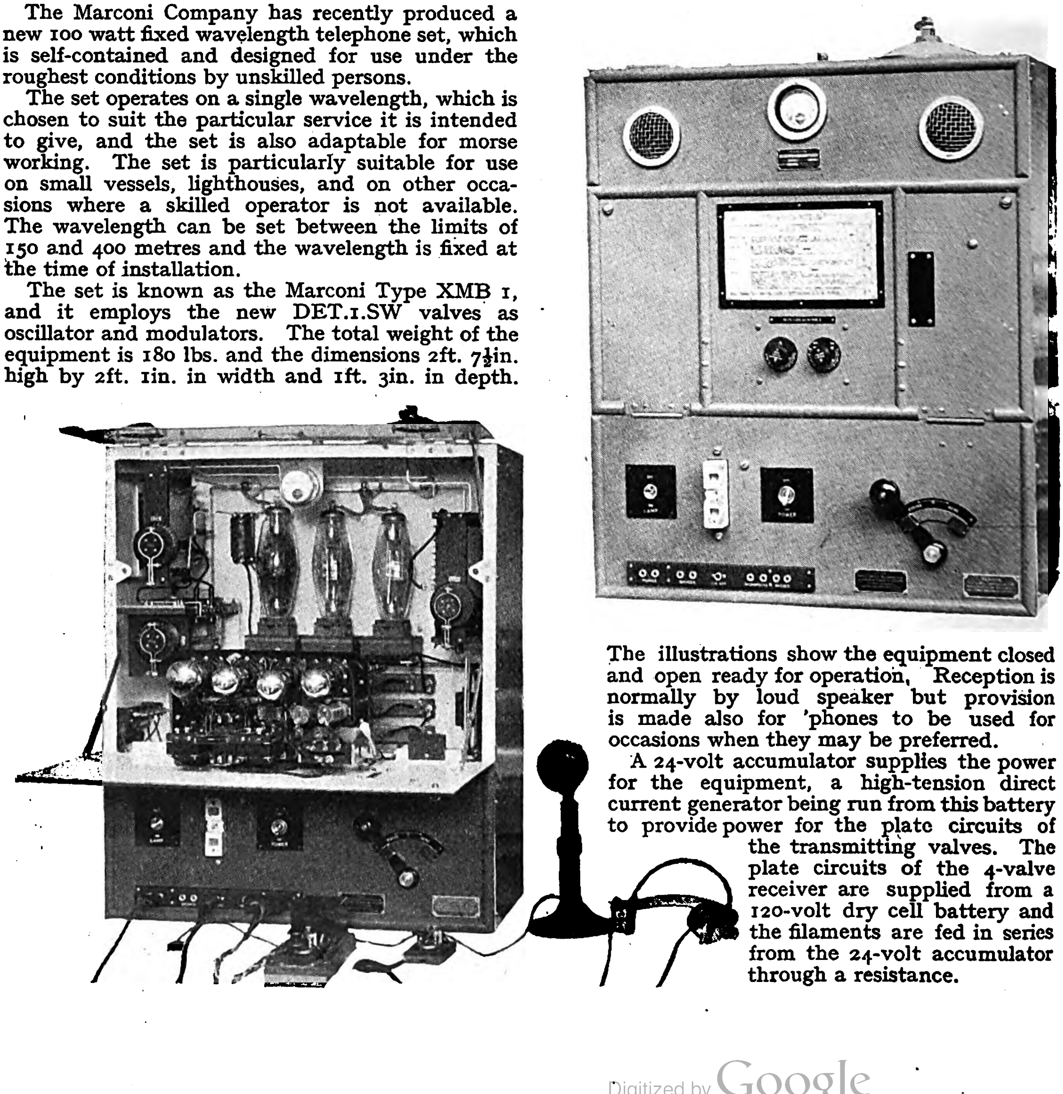
G. W. O. H.

An Interesting New 100 Watt Set.

The Marconi Company has recently produced a new 100 watt fixed wavelength telephone set, which is self-contained and designed for use under the roughest conditions by unskilled persons.

The set operates on a single wavelength, which is chosen to suit the particular service it is intended to give, and the set is also adaptable for morse working. The set is particularly suitable for use on small vessels, lighthouses, and on other occasions where a skilled operator is not available. The wavelength can be set between the limits of 150 and 400 metres and the wavelength is fixed at the time of installation.

The set is known as the Marconi Type XMB 1, and it employs the new DET.1.SW valves as oscillator and modulators. The total weight of the equipment is 180 lbs. and the dimensions 2ft. 7½in. high by 2ft. 1in. in width and 1ft. 3in. in depth.



The illustrations show the equipment closed and open ready for operation. Reception is normally by loud speaker but provision is made also for 'phones to be used for occasions when they may be preferred.

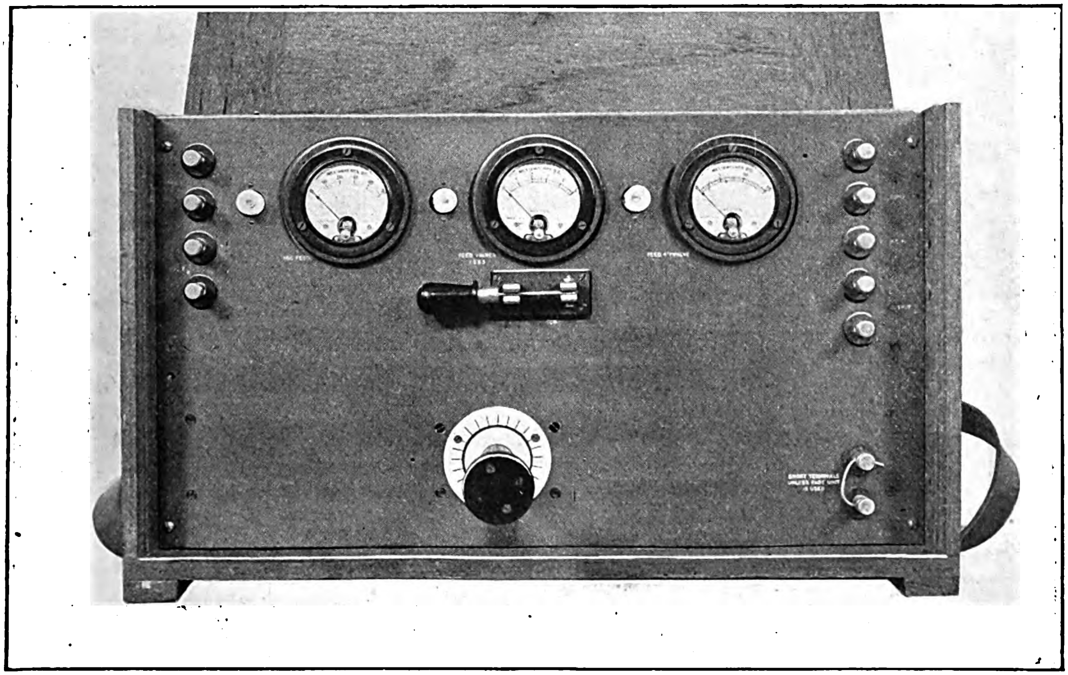
A 24-volt accumulator supplies the power for the equipment, a high-tension direct current generator being run from this battery to provide power for the plate circuits of the transmitting valves. The plate circuits of the 4-valve receiver are supplied from a 120-volt dry cell battery and the filaments are fed in series from the 24-volt accumulator through a resistance.

Microphone Amplifiers and Transformers.

By *H. L. Kirke.*

INTRODUCTION.

THE energy delivered by a microphone in a Broadcast Transmitting System is usually very small, lying between 10^{-12} and 10^{-9} watts, according to the type of microphone; this small amount of energy has to be magnified up to the power necessary to modulate the actual transmitter. The most powerful Broadcasting Transmitter yet built uses about 50 kilowatts in the aerial. The amplifying system may conveniently be divided into three portions, a low-power amplifier, a medium-power amplifier, and a high-power amplifier.



Outside Broadcast Amplifier type 6 *for local lines.*

The low-power amplifier is usually situated close to the microphone. The medium-power amplifier is placed in some central room where all switching operations are carried out. This is called the Control Room. The volume of the electrical impulses supplied from the microphone is usually controlled at this stage before passing on to the transmitter.

The third, or power stage, is usually situated at the transmitting station, which may be situated anywhere within reasonable distance from the control room and is connected thereto by land line. The design of the power amplifying stages will be dealt with later.

Development of Progress.

Before the advent of broadcasting little attention had been paid to accurate reproduction of speech; understandable speech was the sole requirement of the commercial telephone. In this case only the frequencies between 500 and 2,000 were seriously considered. It has been lately realised that even in commercial telephony greater efficiency can be achieved by introducing greater intelligibility, *i.e.* by the use of a wider band of frequencies.

In broadcasting, the ideal must be to reproduce (especially for music) the full audible gamut without distortion of any sort. The chief discouragement to those engaged upon the design of "straightline" amplifiers has been the fact that, in general, loud-speakers seldom produce frequencies below 300 p.p.s. or above 3,000 to 4,000. This state of affairs is at the time of writing rapidly improving.

Frequency Range of Musical Instruments.

The piano has an unusually wide range of notes, the lowest note being of the order of 26 vibrations per second, the highest of the order of 3,500 vibrations per second. The organ is more remarkable, having a range of from 8 to 6,656 p.p.s. The frequency of the various piano octaves is A_3-26, A_2-52, A_1-104, A_0-208, A^1-416, A^2-832, A^3-1,664, A^4-3,328. The violin has a normal frequency range of 212 p.p.s. to 2,560 p.p.s., and when bowed to produce overtones only, up to 3,320 p.p.s. The cello has a range of 64 to 1,540 p.p.s. The bass-fiddle has a range of 64 to 230 p.p.s., and for bowed overtones up to 560 p.p.s. The highest note of a piccolo is 4,112 p.p.s.

All of these notes have overtones (multiples of the fundamental frequency), which give to a note its characteristic tone or timbre. It is only by the degree in which the various overtones are present that we can distinguish the various instruments. It is important, therefore, to reproduce the overtones. In the reproduction of music the low frequencies give colour, fullness and vigour and can almost be considered as foundation stones upon which the remainder is built, while the high frequencies give character and detail. The human voice uses frequencies between 50 and 15,000, but for practical purposes we need consider only those between 100 and 6,000.

The pitch or tone of the voice is determined by a fundamental frequency which lies between 50 and 500 p.p.s. The degree in which the frequencies between 500 and 3,000 are present characterises the vowel sounds, and the frequencies above 3,000 determine the sibilants and hence the intelligibility.

A reproduction of the frequency range 100 to 5,000 will give almost perfect naturalness and intelligibility for human speech, while the reproduction of the range of from 50 to 10,000 will give an extremely adequate picture of any musical rendering. "Cut off" of bass tones will produce lack of "warmth" in music, and cut off of the higher tones takes away brilliancy.

The chief points governing the design of microphone amplifiers are:—

(1) Accuracy of reproduction required.
(2) Overall magnification required.
(3) Amount of output power required.

Accuracy of Reproduction.

By accuracy of reproduction is meant the degree of faithfulness with which the output wave-form is a copy of the input wave-form.

It is convenient to use a unit which might be called the reproduction factor and may be termed the ratio of magnification at any given frequency to that at, say, 600 cycles per second (this frequency is purely arbitrary, 600 cycles being roughly the geometric mean of 35 and 10,000 cycles).

Consider a system consisting of, say, 5 units in cascade: let us call the reproduction factors at a certain frequency of the various units r_1, r_2, r_3, r_4, r_5, etc., then the overall reproduction is $R = r_1 \times r_2 \times r_3 \times r_4 \times r_5$, etc.; if the reproduction factor of each unit is the same, then $R = r_1{}^5$ or $r_1 = R^{1/5}$.

If the reproduction factor of each unit is 0.8 at a certain frequency the overall reproduction factor will be $.8^5 = 0.328$. This shows that if the overall distortion is to be kept small the distortion in each unit must be kept extremely small. The overall desirable reproduction performance is, of course, 100 per cent.; 90 per cent. would be considered extremely good, and 80 per cent. unusually good.

Distortion may be divided into two classes:—

(1) Distortion of the frequency-magnification characteristic.

(2) Distortion of the amplitude-magnification characteristic.

Distortion of the frequency-magnification characteristic, which will be referred to as the frequency characteristic, may be described as the failure of a piece of apparatus to amplify equally at all frequencies within the required frequency range.

Distortion of the amplitude-magnification characteristic—or briefly, the amplitude characteristic—may be described as the failure to amplify equally at all intensities over the required frequency range. It is possible to correct for distortion of frequency characteristic, but not for distortion of amplitude characteristic.

The various causes of distortion and how they may be avoided will now be considered.

Distortion of the Frequency Characteristic.

This may be due to bad design of transformers, too small coupling condensers in resistance-capacity-coupled amplifiers, too low a value of inductance in anode choke, if used, feed back or reaction effects, and badly designed volume-controlling apparatus.

The Transformer.*

In considering the general design of amplifiers it is preferable to consider firstly the design of transformers, as most of the distortion of the frequency characteristic in an amplifying system is due to this cause.

In all microphone amplifiers it is necessary to have both an input and an output transformer since the input is fed from a microphone the impedance of which is usually low (300 ohms or less), whereas the grid-filament impedance of the first valve is very high. The output is usually connected to a land line the impedance of which is too low to be connected directly to a valve. Proposals have been made, notably with the push-pull method of amplification, to avoid the use of an output transformer, but the transformer presents a more practical solution.

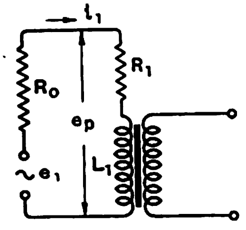


Fig. 1.

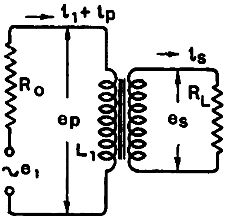


Fig. 2.

Intervalve transformers, while transformers remain imperfect, should never be used, since resistance or choke coupling gives sufficient amplification and can be made to give a sensibly linear characteristic.

Transformers are of two classes—input and output. Intervalve transformers can be considered as input transformers. The input transformer secondary has appreciable self-capacity and is not necessarily loaded, while the output transformer is loaded and has very little self-capacity. The load on an output transformer may change with frequency—notably in the case of a transmission line.

In considering transformer design we are confronted by two problems, one concerned with the high and the other with the low frequencies. For low frequencies all that matters is the primary inductance in relation to the total primary impedance. For high frequencies the transformation ratio, magnetic leakage and secondary self-capacity are the important factors.

Consider first the low frequency problem. It is required to determine the ratio of voltage transformation at some low frequency to that at some medium frequency. Fig. 1 shows a transformer with its secondary unloaded and its primary fed from an E.M.F. e_1 of frequency f_1, with which is associated an internal resistance R_0. R_1 and L_1 are the D.C. resistance and inductance of the primary winding respectively. Then, if e_p is the voltage across the primary winding,

$$e_p = R_1 i_1 + L_1 \frac{di_1}{dt}$$

where i_1 is the primary current.

If i_1 is a sine wave this may be written :—

$$e_p = R_1 i_1 + j\omega_1 L_1 i_1 \text{ (where } \omega_1 = 2\pi f_1).$$

In most practical cases R_1 is very small compared with $\omega_1 L_1$, so that the expression may be written $e_p = j\omega_1 L_1 i_1$ or $i_1 = \dfrac{e_p}{j\omega_1 L_1}$. i_1 is the primary magnetising current and lags 90 degrees behind the impressed voltage e_p. There is also a small current flowing in the primary to supply the iron losses (eddy current and hysteresis) ; this can be represented as a current flowing through a resistance shunted across L_1, but in practice the iron losses are very small so that this effective shunt resistance is very high and can be neglected.

---

* The reader is referred to papers by D. W. Dye, *E.W. & W.E.*, 1924, Vol. I, p. 691 ; P. W. Willans, M.A., before the I.E.E., 1926 ; and by C. H. Naylor, *Electrical Review*, 10th and 17th April, 1925.

Now consider the transformer with its secondary loaded with a resistance R_L, as shown in Fig. 2. Then, if "n" be the ratio of secondary turns to primary turns, the secondary voltage $e_s = ne_p$ and the secondary load current $i_s = \frac{1}{n} . i_p$, where i_p is the primary load current. This load current i_p flows in the primary winding in addition to the magnetising current i_1, which remains unchanged as long as e_p is unchanged, neglecting the small voltage drop in R_1. (The D.C. resistances R_1 and R_2 have been omitted from Fig. 2 for simplification, since they are very small.)

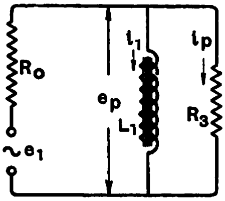


Fig. 3.

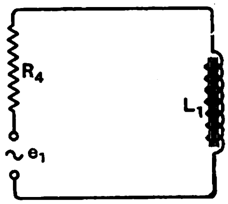


Fig. 4.

Fig. 2 may be redrawn as far as the primary is concerned, as in Fig. 3, where the secondary load R_L of Fig. 2 has been transferred to the primary side, where it has the value $R_3 = \frac{R_L}{n^2}$. That this is so is easily seen, since

$$R_3 \equiv \frac{e_p}{i_p} = \frac{e_s}{n} \cdot \frac{1}{n . i_s} = \frac{1}{n^2} \cdot \frac{e_s}{i_s} = \frac{R_L}{n^2}$$

Now the ratio $\frac{e_p}{e_1}$ will be the ratio that the impedance Z_p of L_1 and R_3 in parallel bears to the total impedance Z_t of the whole circuit considered from e_1. The ratio $\frac{e_s}{e_p}$ being a constant and equal to n, $\frac{e_s}{e_1}$ will therefore depend upon the ratio $\frac{e_p}{e_1}$. It will be seen that at low frequencies the numerical value of Z_p is less than R_3, and that it approaches the value R_3 as the frequency increases. To obtain the reproduction factor at some low frequency it is necessary to determine the value of $\frac{Z_p}{Z_t}$ at that frequency and at some medium frequency, say 600 p.p.s., at which ωL_1 has become so large that its shunting effect is negligible, so that Z_p equals R_3.

Let $a = \frac{Z_p}{Z_t}$ at a low frequency f_1.

$b = \frac{Z_p}{Z_t}$ at a medium frequency f_2 (at which $\omega_2 L_1$ is very large compared with R_3).

$$\text{Then } a = \frac{R_3 j\omega_1 L_1}{R_3 + j\omega_1 L_1} \div \left(R_0 + \frac{R_3 \cdot j\omega_1 L_1}{R_3 + j\omega_1 L_1}\right)$$

$$= \frac{1}{1 + \frac{R_0(R_3 + j\omega_1 L_1)}{R_3 j\omega_1 L_1}}$$

$$\text{and } b = \frac{R_3}{R_0 + R_3}.$$

$$\text{Now } r = \frac{a}{b} = \frac{1}{1 + \frac{R_0 R_3}{(R_0 + R_3) j\omega_1 L_1}}$$

$$\text{Numerically } r = \frac{1}{\sqrt{1 + \left[\frac{R_0 R_3}{\omega_1 L_1 (R_0 + R_3)}\right]^2}}$$

Now if a circuit be drawn as in Fig. 4 the ratio of the reactance $\omega_1 L_1$ to the total impedance from e_1 is

$$\frac{j\omega_1 L_1}{R_4 + j\omega_1 L_1} = \frac{1}{1 + \frac{R_4}{j\omega_1 L_1}}$$

$$= \frac{1}{\sqrt{1 + \left[\frac{R_4}{\omega_1 L_1}\right]^2}} \quad .. \quad (1)$$

numerically.

This expression is identical with the one just obtained for r if $R_4 = \frac{R_0 \times R_3}{R_0 + R_3}$ (*i.e.*, the total resistance of R_0 and R_3 in parallel). For the purpose of determining r, therefore, the two resistances may be conveniently considered as in parallel.

Fig. 5 shows a curve in which the cut-down r is plotted against $\frac{\omega_1 L_1}{R_4}$ where $R_4 = \frac{R_0 . R_3}{R_0 + R_3}$ in Fig. 3.

The value of L affects the cut-down and shows how necessary it is to have a high primary inductance if a good frequency characteristic is to be obtained. The above applies to all types of transformers, but special effects in output transformers will be dealt with later.

As an illustration, reference to Fig. 5 shows that for a cut-down to $r = .95$, the ratio $\frac{\omega_1 L_1}{R_4} = 3$ approx. Therefore, if the value of R_4 be 500Ω, L_1 would have to be 1.20 henries for a cut-down of .95 at 200 p.p.s., 2.4 henries for this cut-down at 100 p.p.s., and 4.8 henries for 50 p.p.s.

The inductance of a coil with a closed iron core varies inversely as the length of magnetic path and directly as the permeability, cross-sectional area, and as the square of the turns, and is given by $L = \frac{4\pi A T^2 \mu}{l} \times 10^{-9}$ where A is the cross-sectional area in cms, T the total number of turns, μ the permeability, and l the length of magnetic path.

The value of μ for Stalloy varies with flux density from a minimum of between 200 to 250 to a maximum of the order of 3,000 for a flux density of about 5,000 lines per square centimetre. Hence for small flux densities the permeability will be of the order of 200 to 250. Transformers for use over a very wide range of flux densities should therefore be designed on a basis of the lowest permeability likely to be met with.

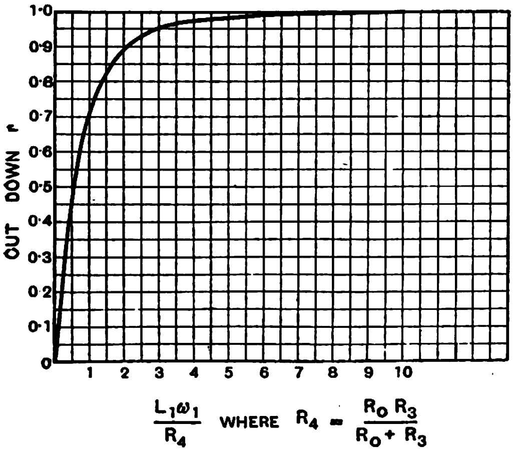


Fig. 5.

The ratio of transformation obtainable depends upon the magnetic leakage, self-capacity, and secondary load in an input transformer.

At the high-frequency end of the scale the design of an input transformer must be dealt with differently from that of an output transformer, due to the effect of secondary self-capacity in the case of the former. The case of the output transformer will be considered first.

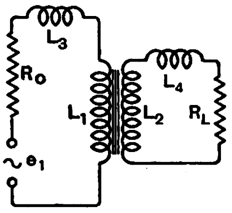


Fig. 6.

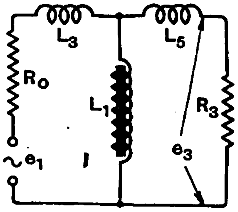


Fig. 7.

All transformers suffer from the effect of magnetic leakage. The coefficient of leakage is a function of the coupling between primary and secondary, the tighter the coupling the less the leakage. The coefficient of coupling is given by $K = \frac{M}{\sqrt{L_1 \times L_2}}$ where L_1, L_2 are the inductances of the primary and secondary windings and M is the mutual inductance between the two windings. The coefficient of leakage is given by $\lambda = 1 - K^2$. Leakage acts in the same way as an inductance in series with the load. The effective value of this leakage inductance bears a definite relationship to the self-inductance of the winding for a given core and type of winding, *i.e.*, $L_3 = L_1 (1 - K^2)$, where L_3 is the effective series inductance due to leakage.

Its effect can best be understood by reference to Figs. 6 and 7. In Fig. 6, R_0 is the internal resistance associated with the source of E.M.F. e_1, L_1 and L_2, the respective primary and secondary inductances, L_3 and L_4, the respective primary and secondary leakage inductances, and R_L, the resistance load on the secondary. In Fig. 7 the impedance across the secondary winding has been referred to the primary winding, as in the case of Fig. 3, the leakage inductance L_5 having the value $\frac{L_4}{n^2}$, and R_3 having the value $\frac{R_L}{n^2}$, where n is the ratio of turns. At high frequencies the reactance ωL_1 is very large compared with the impedance of L_5 and R_3 in series, and its shunting effect can be neglected. The circuit can therefore be considered for the purposes of the frequency characteristic as consisting of R_0, $L_3+L_5=L_6$, and R_3 in series. The ratio $\frac{e_3}{e_1}$, which is representative of the frequency characteristic, will be given by:—

$$\frac{e_3}{e_1} = \frac{R_3}{R_0 + R_3 + j\omega_3 L_6} = a$$

where $\omega_3 = 2\pi f_3$, f_3 being a high frequency for which the reproduction factor is required.

At a medium frequency f_2, at which $\omega_2 L_6$ is small compared with $R_3 + R_0$,

$$\frac{e_3}{e_1} = \frac{R_3}{R_0 + R_3} = b.$$

Now the reproduction factor or cut-down is given by $r = \frac{a}{b} = \cfrac{1}{1 + \cfrac{j\omega_3 L_6}{R_0 + R_3}}$

$$\text{Numerically, } r = \frac{1}{\sqrt{1 + \left(\frac{\omega_3 L_6}{R_0 + R_3}\right)^2}}$$

$$\therefore \quad \frac{\omega_3 L_6}{R_0 + R_3} = \sqrt{\frac{1}{r^2} - 1}$$

As an example, if the value of r is to be 0.95 at 5,000 p.p.s. and $R_0 = R_3 = 1{,}000$ ohms, then L_6 must be .0210 henries, or, if the same cut-down is required at 10,000 p.p.s., L_6 must be only .0105 henries.

For a Stalloy core having a cross-sectional area of 5.5 sq. cms. approximately and a length of magnetic path of 18 cms., the leakage coefficient $\frac{L_6}{L_1}$ varies between .005 and .02 according to spacing between the windings and the method of winding. Taking a mean value of .01, then, for a cut-down to 0.95 at 10,000 p.p.s., since L_6 must be .0105 henries, L_1 will be 1.05 henries. Now from Fig. 5 it is known that for a cut-down to 0.95 at a low frequency f_1, $\frac{\omega_1 . L_1}{R_4} = 3$, therefore in this case $\omega_1 L_1 = 3 \times 500 = 1{,}500$ ohms.

$$\therefore \quad \omega_1 = \frac{1500}{1.05} = 1{,}430$$

$$\therefore \quad f_1 = \frac{1410}{2\pi} = 228 \text{ p.p.s.}$$

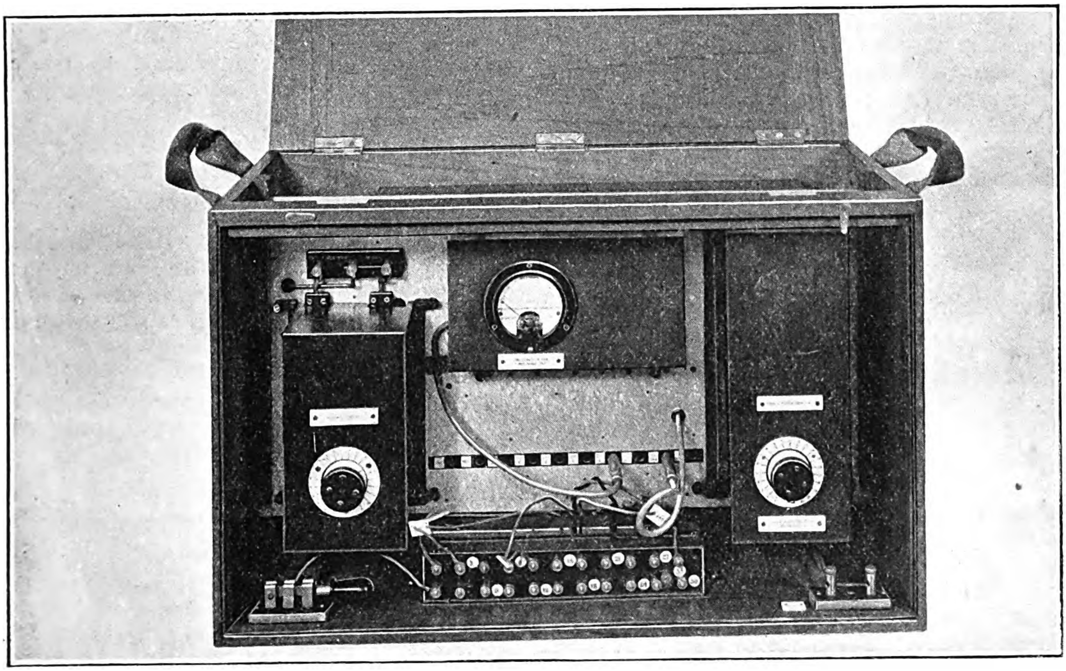
The cut-down at 50 p.p.s. would be .555.

As previously explained, an overall cut-down to 0.95 would be good, but a cut-down to .95 in each transformer in a case where there were five transformers in the chain would be an overall cut-down of $0.95^5 = .77$ at 228 p.p.s., and a cut-down of $.555^5 = .053$ at 50 p.p.s., which would be very bad.

For the value of r of 0.95 at 5,000 p.p.s. the leakage inductance of the winding must be .0210 henries. With a leakage coefficient of .01 this fixes the primary inductance as 2.10 henries, which gives a value of $r = 0.95$ at 114.0 p.p.s. and gives $r = 0.80$ at 50 p.p.s. It should be observed that the frequency band-width, $\frac{f_3}{f_1}$ is the same as in the previous case, the loss of high frequencies being compensated for by a gain of low frequencies. Now if the leakage coefficient can be halved, then for the same value of primary inductance the leakage inductance will be reduced to .0105 henries, which gives a value of $r = 0.95$ at 10,000 p.p.s. Hence by halving the leakage coefficient the frequency band-width $\frac{f_3}{f_1}$ for a given cut-down can be doubled. The advantage of halving the leakage coefficient may be used to improve the low frequencies instead of the high frequencies by doubling the primary inductance (*i.e.*, by increasing the primary turns in the ratio $\sqrt{2}/1$), in which case the value of $r = 0.95$ is obtained at the frequencies 57 p.p.s. and 5,000 p.p.s., the frequency band-width being doubled as before. These two examples illustrate the general principle that the frequency band-width obtainable for a given cut-down r is inversely proportional to the leakage coefficient, whether the reduction of leakage coefficient be utilised to improve the high frequencies, the low frequencies, or both.

The foregoing examples illustrate the difficulty of designing an output transformer to operate with a matched impedance load, that is for the condition $R_3 = R_0$. Good reproduction at the low frequencies demands a high primary inductance; but as the inductance is increased the leakage inductance is proportionately increased (for a given type of core and winding), and therefore the term $\omega_3 L_6$ is increased compared with $(R_3 + R_0)$, so increasing the cut-down at high frequencies. The simplest method of reducing the effect of leakage is to increase the value of R_3 (Fig. 7) by increasing the ratio of turns. This, of course, reduces the efficiency and also, when R_0 represents a valve impedance, reduces the maximum output obtainable from the valve.

Consider a transformer as in Fig. 6 loaded with a resistance R_L of 500 ohms, operating from a valve for which $R_0 = 1{,}000$ ohms. Then for matched impedance the turns ratio would be $\sqrt{2}$, so that R_3 (Fig. 7) $= 1{,}000$ ohms. Now if the ratio of turns be increased from $\sqrt{2}$ to $\sqrt{2} \times \sqrt{5}$*, R_3 becomes $500 \times 10 = 5{,}000$ ohms. Then, if r is to be 0.95 at 5,000 p.p.s., $L_6 = \dfrac{\sqrt{\frac{1}{r^2} - 1}\,(R_0 + R_3)}{\omega_3} =$ .0630 hys. Therefore, for a leakage coefficient of .01, L_1 will be 6.30 henries. Then at 50 p.p.s. ω_1, L_1 will be 1,980 ohms, and $R_4 = \dfrac{R_0 \times R_3}{R_0 + R_3} = 834$ ohms. $\therefore \dfrac{\omega_1 L_1}{R_4} = \dfrac{1980}{834} = 2.38$, and therefore from Fig. 5 $r = 0.925$. The reproduction factor at 50 p.p.s. has thus been improved by this means from 0.80 to 0.92. The value $r = 0.95$ is obtained at the frequency of 64 p.p.s. The band-width has thus been improved from 5,000/114 to 5,000/64, *i.e.* 78 per cent.



Outside Broadcast Amplifier type 5 for long lines.

The loss of efficiency due to this may be calculated as follows :—

For the matched impedance condition—*i.e.*, when $R_3 = R_0$, at medium frequencies $e_3 = \dfrac{e_1}{2}$ and $e_s = \dfrac{e_3}{\sqrt{2}} = \dfrac{e_1}{2\sqrt{2}}$. Output power p_1 is therefore $\dfrac{e_1^2}{8} \cdot \dfrac{1}{500} = .25\ e_1^2$ milliwatts (if e_1 is expressed in volts). For the condition when $R_3 = 5{,}000$ ohms, $e_3 = \dfrac{5}{6}\ e_1$ and $e_s = \dfrac{e_3}{\sqrt{10}} = \dfrac{5}{6\sqrt{10}}\ e_1$. Therefore output power

---

* A value chosen empirically.

p_2 is $\frac{25}{360} e_1^2 \times \frac{1}{500} = .139\, e_1^2$ milliwatts. The ratio of efficiencies is therefore $\frac{p_2}{p_1} = \frac{.139}{.25} = 0.55$, so that the loss of efficiency is 45 per cent.

The leakage coefficient can only be decreased for a given type of core by decreasing the spacing between sections, and this cannot usually be done owing to the increase of capacity which must result.

If the transformer is wound in several sections and the sections packed closely (*i.e.*, no spacing between them) and the primary and secondary interleaved, the leakage coefficient may be reduced to about .005, at the expense of increased interwinding capacity. With a leakage coefficient of .005 a transformer having matched impedance windings can be designed so that its performance factor is $r = .95$ at 50 and 4,400 p.p.s. or at 100 and 8,800 p.p.s.

For a transformer having an increased ratio to reduce the leakage effect, as explained above, then for an increased ratio of $\frac{1}{\sqrt{5}}$ $r = .95$ at 50 and 7,850 p.p.s.

So far the design of an output transformer has only been considered for a load of equal impedance at all frequencies. In a transmission line, however, the impedance and phase angle vary with frequency, particularly for unloaded lines, and in consequence the output transformer must be designed to meet all loads at all frequencies in the same way that a commercial power transformer must have a good regulation factor for varying loads at one frequency. If the impedance of the transmission line varies with frequency, then the voltage and current, and therefore power, in the line will also vary with frequency. If the transformer is designed to take the load of the mean impedance, the voltage and current at the sending end will vary with frequency. If the transformer is designed so that R_0 (Fig. 3) is high compared with R_3 (*i.e.*, its output impedance being high in relation to the load), then the load current will be nearly equal at all frequencies (constant current condition). If R_3 is made high compared with R_0 at all frequencies, then the voltage across the load will be nearly constant at all frequencies (constant voltage condition). All this is assuming constant E.M.F. e_1. In practice it is found preferable to aim at constant voltage, because for any line the ratio of received to transmitted current varies more with frequency than the ratio of received to transmitted volts.

In order to obtain the constant voltage condition it is necessary to make the effective primary impedance (when the secondary is loaded) high compared with R_0; that is to say, the effective impedance of the output circuit, looked at from the line, must be low compared with that of the line at any frequency. This is the same as saying that the voltage regulation for all loads must be good. It has been found that for the average line, if the output impedance is made 100 ohms actual, the frequency characteristic $\frac{\text{line volts}}{\text{grid volts}}$ will be practically straight.

Input Transformers.

The essential difference, as has been said before, between an input and an output transformer is that the secondary of an input transformer has self-capacity, and that the secondary winding need not necessarily be loaded.

An input transformer is usually designed so that its primary has a certain impedance which matches the mean impedance of the input circuit.

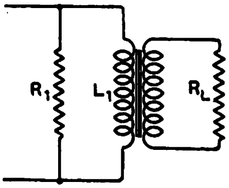


Fig. 8.

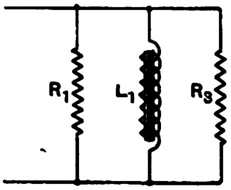


Fig. 9.

For a microphone this impedance is usually between 100 and 300 ohms, depending on the type of microphone. When the input transformer has to work from a line it is usual to design the effective impedance between 200 and 1,000 ohms, according to the type of line. A value of 500 ohms has been found convenient. This impedance may be made up of primary load, secondary load, or a combination of both. Reference to Figs. 8 and 9 will show this clearly. The secondary load R_L (Fig. 8) has been referred to the primary side in Fig. 9, where it has the value $R_3 = \frac{R_L}{n^2}$. The total input impedance, for all except very low frequencies, is $Z = \frac{R_3 . R_1}{R_3 + R_1}$, ωL_1 being high compared with Z.

The actual values of R_1 and R_L will depend upon the frequency characteristic required, the secondary leakage and capacity, and partly upon the ratio of transformation.

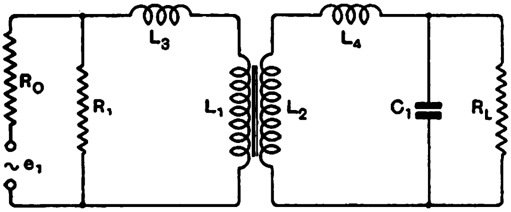


Fig. 10.

Fig. 10 shows a transformer having primary and secondary loads R_1 and R_L, primary and secondary leakages L_3 and L_4 and capacity C_1. Fig. 11 shows the same transformer viewed from the primary side, in which

$$L_5 = \frac{L_4}{n^2} \text{ and } C_2 = n^2 C_1$$

$$\left(n \text{ being } \frac{\text{Secondary turns}}{\text{Primary turns}}\right).$$

At high frequencies the reactance of L_1 is very large and its shunting effect is negligible. Then, if there were no primary and secondary loads the circuit would consist of R_0, $L_3 + L_5 = L_6$, and C_2 in series. Actually there would be very slight damping across C_2 representing iron losses. This is essentially a resonant circuit, and the shape of the frequency characteristic of such a transformer would depend largely upon the value of R_0. The effect of R_3 is to flatten the curve and make it independent of R_0. The ratio $\frac{L_6}{C_2}$ can be varied by altering the spacing between the sections, this varying the damping of the circuit. The product $L_6 C_2$ can be varied by altering the secondary turns; this determines the frequency of the resonance peak, which when correctly damped by R_3 will be the point at which the high frequency cut-off begins. The effect of R_3 in damping the circuit is shown in the curves of Fig. 12. Curve (*a*) is obtained with the secondary open-circuited, curve (*b*) for one value of R_3, and curve (*c*) for a smaller value. (In these curves the amplitude has in each case been brought to 1 for 500 p.p.s. for purposes of comparison.)

Therefore, in designing an input transformer it is first necessary to choose such a value of secondary turns that the leakage inductance cum self-capacity resonant frequency is not lower than the highest frequency it is desired to transmit. The next step is to choose the ratio $\frac{L_6}{C_2}$ together with the value of R_3 such that the curve (*a*) of Fig. 12 is reduced to curve (*b*) with any value of R_0 (the resonant peak will be more prominent the lower R_0).

The primary turns are then determined by the amount of cut-down allowable at some definite low frequency according to equation (1), where the R_4 of equation (1) is the total resistance of R_3, R_1, and R_0 in parallel (Fig. 11).

In practice it has been found that a transformer for 500 ohms input impedance, having a value of r of not less than .95 at 50 and 9,000 p.p.s., may have the following dimensions:—

Core area 5.5 sq. cms. } Stalloy.
Core length 18 cms. }
Primary turns, 2,040 in 4 sections. } Sections interleaved.
Secondary turns, 11,250 in 5 sections. }
Secondary load resistance, 70,000 to 100,000 ohms.
Primary load resistance, 640.

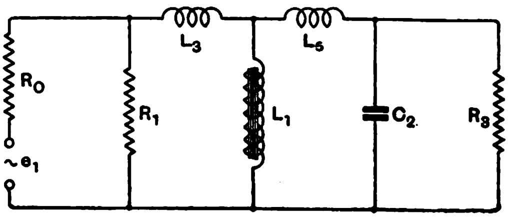


Fig. 11.

The above transformer has the advantage that the input phase angle is small for all frequencies from 50 to 9,000.

It is possible to improve the overall

performance of transformers very considerably by the use of iron of higher initial permeability than that of Stalloy, the initial permeability being the permeability of the iron for very low values of flux density (values between 0 and 50 lines /sq. cm.).

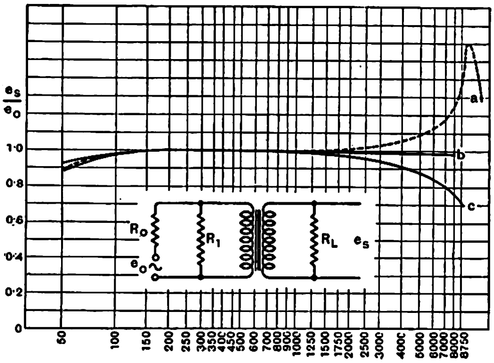
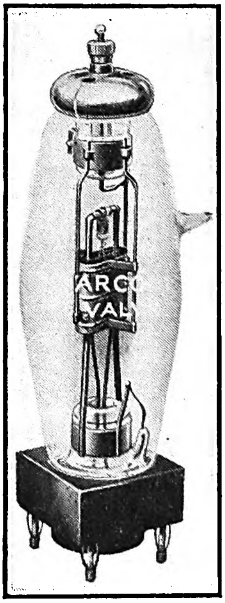


Fig. 12. *Curves show effect of altering secondary low resistance R_L.*

One kind of iron suitable for this purpose is an alloy of iron and nickel called nickel-iron, which has an initial permeability of about 600 compared with the value of 250 for Stalloy. As the flux density is increased the permeability increases, but this increase is much greater in the case of Stalloy than in the case of nickel iron, so that at a flux density of about 100 lines/sq. cm. the μ for Stalloy is equal to that for nickel iron, and at higher flux densities the former exceeds the latter. The use of nickel-iron is therefore only advantageous in transformers where the working flux density is normally low; this is the case in both input and output transformers of microphone amplifiers, although in the output transformer the flux density may sometimes rise to 200 lines/sq. cm. The reason for the improvement in overall performance is that the leakage coefficient is inversely proportional to the permeability of the iron, since with a given number of turns on a given size of core, if the permeability be increased "*n*" times, the primary inductance will be increased "*n*" times, whereas the leakage inductance remains unaltered since the leakage flux is wholly in the air space outside the core. The reduction of leakage coefficient by using nickel iron is therefore $\frac{250}{600}$, and the frequency band for a given value of r is correspondingly increased as previously explained. Nickel iron is a robust material and retains its magnetic properties as well as Stalloy. Another material of high initial permeability is an alloy of iron, nickel and copper called Mumetal, the value of initial permeability being about 3,000. The magnetic properties of this alloy are obtained by heat treatment, and it must not be subjected to mechanical shock or excessive heating. Using this alloy it has been possible to obtain a leakage coefficient as low as .0003, and transformers can be designed with it having a frequency band of 50 to 8,000 for an r value of 0.98.

(*To be concluded.*)

Short-wave Transmitting Valve.



THE well-known Marconi D.E.T.1. valve is now produced in a special form for short-wave work and is available for amateur use under the designation D.E.T.1.SW. Originally developed for use with the Beam system the new valve is of the double-ended type and is suitable for wavelengths down to 10 metres. The filament consumption is 2 amps. at 6 volts, the amplification factor and impedance are 8.5 and 5,000 respectively, and the valve is rated at 30 watts.

Supplies are now available and the price is £7 5s. 0d.

Reactance and Admittance Curves.

Applied to Tuned Circuits With and Without Resistance.

By L. T. Bird.

(Concluded from page 334 *of June issue.)*

Resistance in a Resonant Circuit.

It is now possible to study the general case of a resonant circuit in which the resistance of the coil and the leakance of the condenser are both taken into account. Consider first the series resonant circuit shown in Fig. 9a. The two portions of which this circuit is made up have already been considered separately, and it is now only necessary to see how they combine. The two portions being in series, assume unit current to flow through the circuit. It is then merely necessary to discover how the voltages across the two portions combine to obtain an impedance curve of the complete circuit. For this purpose the vector diagrams provide invaluable aid. The diagrams of the separate portions are shown in Figs. 7a and 8c.

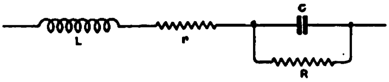


Fig. 9a.

The connecting link between the two diagrams is the vector representing the constant current of one ampere. In Fig. 7a this is OD and in Fig. 8c it is OQ. These being identical the diagrams may be combined as in Fig. 9b, and the phase relationship between the voltage OC across the inductance and the voltage OS across the capacity becomes apparent. The vector sum of these two voltages is the required total voltage and is shown as OX.

It is interesting to note how the appearance of this diagram alters with the frequency. When the frequency is low, S will be high on the semi-circle and C will be near A. Thus OS will be greater than OC and the resultant voltage vector will be on the right of OA. As the frequency increases, the point C moves further along to the left on the line AC and S moves downwards on the semi-circle. Thus OS gets shorter and OC longer, and OX approaches the line OT. At a certain frequency OX becomes vertical and the total voltage is in phase with the current. As the frequency is still further increased OX moves over to the left of OT and increases in length again. When the values of resistance, inductance and capacity are such as obtain in normal radio circuits the length of OX is a minimum at the same time as it comes into phase with OA.

This diagram is the basis of the following method of drawing the complete impedance curve of such a circuit. Draw as before the reactance curve of the inductance and the impedance curve of the combination of condenser and resistance in parallel (Fig. 9c). Draw AA' parallel to OO' at a height equal (on the scale of the diagram) to the value r of the resistance in series with the inductance. Mark off OT equal to R, the resistance across the condenser, and describe a semi-circle thereon, select a frequency (say at F, Fig. 9c) and erect ordinates FG and FH to the reactance and impedance curves. Mark off along AA' a length AC equal to FG. With centre O and radius FH describe an arc cutting the semi-circle in S. The line CS will be a measure of the impedance of the circuit at the frequency considered, and if erected at F as an ordinate will give a point on the impedance curve.

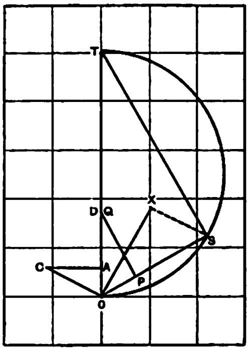


Fig. 9b.

The connection between this construction and the vector diagram of Fig. 9b will become more apparent from 9e and 9f, where the essential part of the construction is compared with the vector diagram as normally drawn. Fig. 9d is an intermediate step between the two, where OA is drawn downwards from O and AC to the right from A. This has the effect of reversing the direction of OC. Since SX and OC are equal and parallel, figure $OXSC$ is a parallelogram; therefore OX and SC are equal and parallel. Hence CS is equal to OX. Since OX represents the value of the total voltage for unit current, CS is a measure of the impedance of the circuit; and since $\widehat{XOT} = \widehat{SCV}$ the inclination of CS to the vertical is the angle of phase difference between current and voltage at the frequency considered.

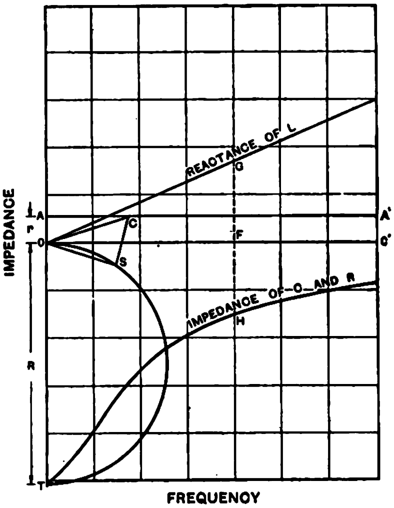


Fig. 9c.

Fig. 9e is identical with Fig. 9d, except that it is drawn, upside down as it were, for comparison with Fig. 9c. A repetition of this construction for several frequencies will yield a series of points through which the impedance curve may be drawn. Preserving the convention that leading currents and lagging voltages are plotted as negative quantities, the impedance diagram appears as in Fig. 9f, where it is drawn for a concrete case. By plotting the inverse of a series of values of the impedance the admittance curve may be drawn therefrom. Both these curves show a marked difference from those obtained by neglecting the effect of resistance. The impedance is never actually zero, but has a minimum value at "tune point," where the total voltage is in phase with the current. Similarly, the admittance does not rise to infinity, but to a definite maximum at the same point. Very often at this stage the convention relating to leading voltages and lagging currents is dropped and all values are shown as positive. This is then referred to as a resonance curve.

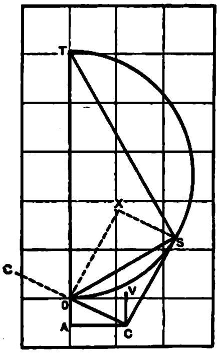


Fig. 9d.

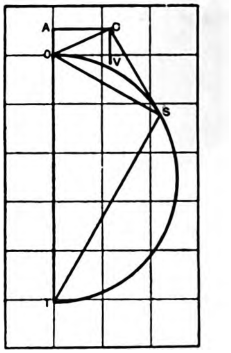


Fig. 9e.

The case of the parallel resonance curve is very similar. Consider unit voltage to be applied across the circuit of Fig. 10a. The two parts of the circuit will behave as if separate, but the currents to each part will combine in the common lead. The voltage vector is the connecting link between the respective diagrams. The combined figure

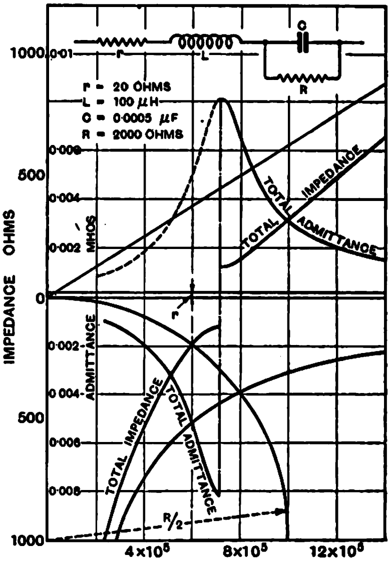


Fig. 9f.

(10a) is similar to that for the series case, and hence no detailed explanation need be given.

The construction for drawing the admittance curve of the circuit may be given thus. Draw the admittance curve of L and r in series, and the admittance curve of C (Fig. 10b), also a line parallel with the axis, at a distance equal on the scale of the diagram to the leakance of the condenser in mhos. Mark off OE equal to $1/r$ and describe a semi-circle thereon; select a frequency and erect ordinates to the admittance curves already drawn. From O mark off the admittance of L and r as a chord OD of the semi-circle, and from P the admittance PQ of C along PP'. The line joining the two points D and Q so obtained gives on the scale of the diagram the total admittance at this frequency, together with the angle of phase difference between supply current and voltage. In Fig. 10c this construction has been followed for the same values of L, r, C and R as in the series case.

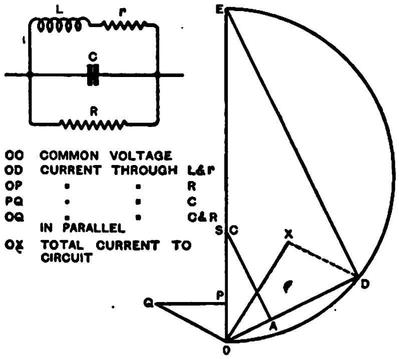


Fig. 10a.

It may have been remarked that in the concrete case worked out the values of the resistances chosen are somewhat heavy, and are such as would be obtained only by deliberately damping the circuit. A second case is shown worked out in Fig. 10d, where the resistance of the coil is taken as 8 ohms and the insulation resistance of the condenser as 10,000 ohms.

Observe the effect on the diagrams. The maximum value of total impedance has increased considerably (the scale has been reduced to get the curve on to the paper) and the peak of the curve has become much sharper, *i.e.* the interesting part of the diagram covers a smaller range of frequencies. In addition to this the actual construction for finding the impedance of the circuit around resonant frequency occupies a more confined space, shown by the dotted rectangles (Figs. 10c and 10d). It is within this rectangle that all such points as SC (Fig. 10a) fall for frequencies around resonance.

If r is still smaller and R bigger, the resonance peak becomes yet sharper and the space containing the essential work more and more confined.

Some modification of the construction is therefore necessary to make the method practical for lightly damped circuits. The scale must be magnified considerably and the diagram restricted to frequencies around resonance. This is readily achieved in practice by reason of the fact that, when r is small and R large, certain approximations become justifiable.

Consider the parallel circuit.

(1) If r is small in comparison with $L\omega$ at resonance, the arc of the semi-circle upon which the essential part of the construction is made may be drawn as the curve of $\frac{r}{L^2\omega^2}$, and this curve is indistinguishable from a straight line parallel with the frequency axis ($\frac{r}{L^2\omega^2}$ being sensibly constant over the range considered).

(2) Instead of marking off along the semi-circle a chord whose length represents the admittance of L and r, it is equally accurate to mark off along the frequency axis a length equal to $1/L\omega$ and erect an ordinate to the arc of the semi-circle (now drawn as a straight line).

(3) If the resonance curve occupies only a narrow band of frequencies, the portion of the curve of $1/L\omega$ which comes into the construction will be found to be for all practical purposes a straight line.

These approximations may be rendered more acceptable by considering a concrete example.

Let $L = 100\ \mu$H. and $C = .0005\ \mu$F as before. Let r be .05 ohms and R be 5 megohms. Referring to Fig. 10b, OD is the admittance of L and r in series.

$$\therefore \qquad OD = \frac{1}{\sqrt{r^2 + L^2\omega^2}}$$

Now, since ODE and OJD are similar triangles,

$$JD/OD = OD/OE$$

$$\therefore \quad JD = OD^2/OE$$

$$= \frac{\dfrac{1}{r^2 + L^2\omega^2}}{1/r}$$

$$= \frac{r}{r^2 + L^2\omega^2}$$

$$= \frac{1}{r + \dfrac{L^2\omega^2}{r}}$$

For the values under consideration it will be found that r is negligible in comparison with $\frac{L^2\omega^2}{r}$. At resonance $\frac{L^2\omega^2}{r} = \frac{440^2}{.05} = 4 \times 10^6$ approx., whilst $r = .05$. Hence JD may be taken as $\frac{r}{L^2\omega^2}$, *i.e.* the curve of $\frac{r}{L^2\omega^2}$ near resonance is a very close approximation of that part of the semi-circle made use of in the construction.

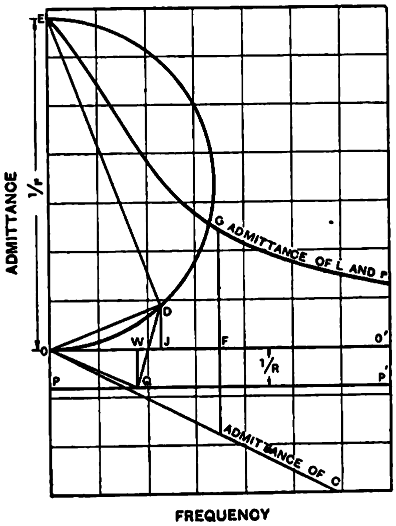


Fig. 10b.

Now for the values of r and R considered, the essential part of the resonance curve covers a band of frequencies from about 711,000 to 712,500, *i.e.* ω varies from about 4,467,000 to 4,477,000.

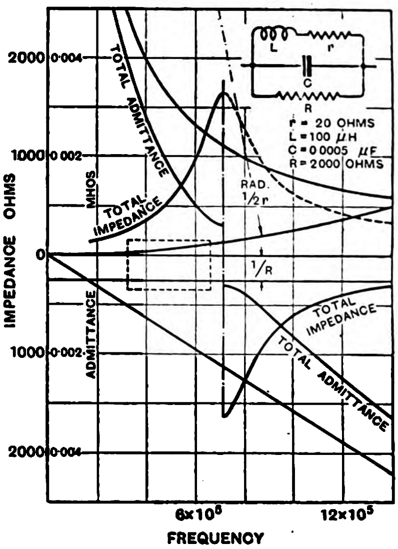


Fig. 10c.

When $\omega = 4{,}467{,}000$

$$\frac{r}{L^2\omega^2} = .2506 \times 10^{-6}.$$

When $\omega = 4{,}477{,}000$

$$\frac{r}{L^2\omega^2} = .2495 \times 10^{-6}.$$

On the scale of the diagram there is no appreciable difference between these two quantities. Hence for all practical purposes the essential arc of the semi-circle may be drawn as a straight line parallel with the axis and distant from it $r/L^2\omega^2$ on the scale of mhos. (Approximation No. 1.)

Now consider the line OJ.

Since OED and OJD are similar triangles,

$$OJ/OD = ED/EO.$$

$$\therefore \quad OJ = \frac{OD \,.\, ED}{EO}$$

Now $ED = \sqrt{OE^2 - OD^2}$

$$= \sqrt{\frac{1}{r^2} - \frac{1}{r^2 + L^2\omega^2}}$$

$$= \sqrt{\frac{L^2\omega^2}{r^2\,(r^2 + L^2\omega^2)}}$$

$$= \frac{L\omega}{r\sqrt{r^2 + L^2\omega^2}}$$

$$\therefore \quad OJ = \frac{\dfrac{1}{\sqrt{r^2 + L^2\omega^2}} \quad \dfrac{L\omega}{r\sqrt{r^2 + L^2\omega^2}}}{1/r}$$

$$= \frac{L\omega}{r^2 + L^2\omega^2}$$

$$= \frac{1}{r^2/L\omega + L\omega}$$

As previously stated throughout the range considered, ω varies from 4,467,000 to 4,477,000.

$$\therefore \quad r^2/L\omega = \frac{.0025}{447} = .000006 \text{ approx.}$$

which is a minutely small quantity compared with 447, the value of $L\omega$. Thus $r^2/L\omega$ may be neglected in comparison with $L\omega$, and without serious error the length of OJ be taken as $\frac{1}{L\omega.}$ Instead, therefore, of marking off as a chord of the semi-circle the value of the admittance of L and r, it is equally accurate, when r is small compared with $L\omega$, to mark off along OO^1 a distance OJ equal to $\frac{1}{L\omega}$ and erect at J an ordinate cutting the semi-circle in D (approximation No. 2).

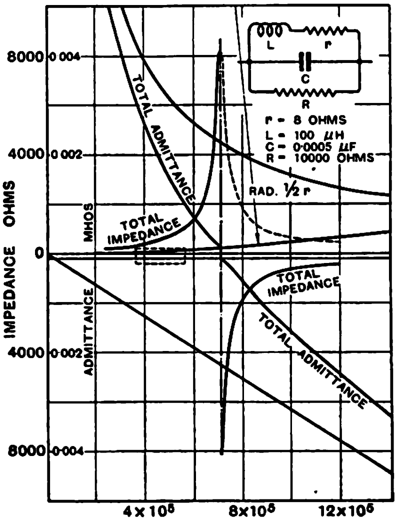


Fig. 10d.

It has already been shown that $r/L^2\omega^2$ is appreciably constant over the peak of the resonance curve. Now r and L are themselves constant quantities, hence the expression $-\frac{1}{L\omega^2}$ will also be appreciably constant. This is the measure of the slope of the curve of $1/L\omega$ for any value of ω. If this be constant the curve of $1/L\omega$ is a straight line (approximation No. 3).

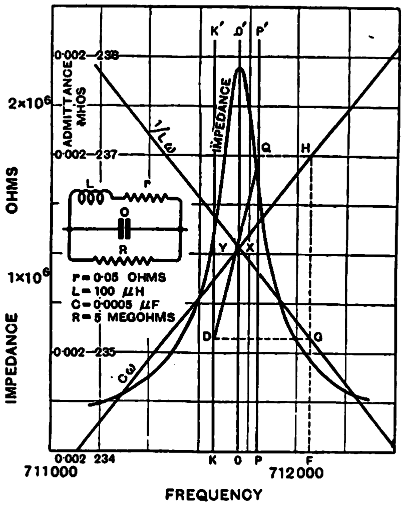


Fig. 11.

All that remains, therefore, is to enlarge the scale of the diagram by restricting the frequencies to those around resonance, and to rearrange the construction to make it more readily workable.

Thus (Fig. 11) lay out a horizontal axis of frequency and plot vertically as positive quantities the values of $C\omega$ and $1/L\omega$. These will both appear as straight lines and will intersect at a point X. Through this point draw a vertical line OO' (O will be the resonant frequency). On the left of this line erect a parallel line KK' distant $r/L^2\omega^2$ on the scale of mhos already adopted. On the right of it erect a third parallel line PP' distant from it $1/R$ on the same scale. To find the total admittance at a given frequency (say at F) erect a perpendicular cutting the $C\omega$ and $1/L\omega$ curves in H and G respectively. From H draw HQ horizontally cutting PP' in Q. From G draw GD horizontally cutting KK' in D. DQ will be a measure of the total admittance of the circuit at the frequency considered. The inverse of this value will be the impedance of the circuit. (This is shown worked out for the last mentioned values of L, r, C and R.)

This construction may be identified with the previous figure as follows. The curve of $1/L\omega$ corresponds with the admittance curve of L and r, except that the scale of admittance has been moved. The curve of $C\omega$ is the same as before except that the values are now shown as positive. KK' represents a portion of the semi-circle and PP' the line PP' of Fig. 10b. These lines have been drawn vertical instead of horizontal to make the marking off of $1/L\omega$ along KK' and $C\omega$ along PP' more of an automatic process.

Since the curves of $1/L\omega$ and $C\omega$ are in effect straight lines the expression connecting such lengths as KD and PQ with the frequency will be a linear one, and it would be possible to plot as a linear scale along KK' a series of points such as D and to label them with the frequencies to which they correspond. This would give along KK' a frequency scale $\frac{1}{2\pi C}$ times the admittance scale, and as the slopes of these curves are equal and opposite

(N.B.—Slope of curve $\frac{1}{2\pi fL} = -\frac{1}{2\pi f^2L}$.

Slope of curve $2\pi fC = 2\pi C$

and near resonance $f^2 = \frac{1}{4\pi^2LC}$

i.e., $2\pi C = \frac{1}{2\pi f^2L}$)

all such lines as DQ will intersect at a point Y, which falls midway between KK' and PP' and immediately opposite point X. Having found the position of Y, to find the admittance of the circuit join Y to the point on the scale corresponding to the chosen frequency and double its length.

This suggests a further modification eliminating quite a deal of labour and making it possible to obtain the impedance curve directly by graphical methods.

Lay out along a line ZZ' (Fig. 12) a scale of frequency so that f_0, the resonant frequency, occurs at the centre point Y $\left(f_0 = \frac{1}{2\pi\sqrt{LC}}\right)$. At Y erect YY' perpendicular to ZZ'. Lay out along YY' a scale of admittance $4\pi C$ times the scale of frequency (or what is the same thing $\frac{1}{\pi f_0^2 L}$ times the scale of frequency). This scale will be in mhos. Mark off along YY' a length YW, so that $YW = \frac{r}{L^2\omega^2} + \frac{1}{R}$ on the admittance scale (N.B.—To make a reasonable figure the scale of frequency must be so chosen that ZZ' is of the order of twenty times the length of YW). Through W draw KK' parallel to ZZ'. Lay off also along YY' a convenient impedance scale and make YV on this scale equal to $\frac{1}{r/L^2\omega_0^2 + 1/R}$, *i.e.* $1/YW$. With centre Y and radius YV describe a semi-circle on ZZ'.

To find for a given frequency:

(1) The impedance of the circuit.

(2) The admittance of the circuit.

(3) The angle of phase difference between supply voltage and current.

At the selected frequency, F, draw FH perpendicular to ZZ', cutting KK' in D and the semi-circle in H. Join YD and produce so as to cut the semi-circle in M. Draw MN parallel to ZZ', cutting FH in N.

Then

(1) FN on the impedance scale is the impedance of the circuit (*i.e.*, N is a point on the impedance curve).

(2) YD on the admittance scale is the admittance of the circuit.

(3) $\widehat{DYY'}$ is the angle of phase difference.

Comparing this with Fig. 11, KK' corresponds with KK' and the point Y with point Y. The factor connecting the scales of frequency and admittance has, however, been doubled so as to make such lengths as YD show the admittance direct instead of half that quantity as in Fig. 11.

The fact that FN is a measure of the impedance of the circuit may be demonstrated thus:

Draw MJ perpendicular to ZZ'. MJY and DFY are similar triangles.

Hence $MJ/MY = DF/DY$.

Now $DF = YW$, $MY = YV$ and $MJ = FN$

$$\therefore \quad FN/YV = YW/DY$$

$$\therefore \quad FN = \frac{YW \,.\, YV}{DY}.$$

But the scales are so chosen that

$$YV = 1/YW \quad \because \quad YV \,.\, YW = 1$$

$$\therefore \qquad FN = 1/DY.$$

But DY represents the admittance of the circuit; therefore FN represents on the impedance scale the impedance of the circuit.

On plotting such points as N for various frequencies, the resonance curve for the given circuit may be drawn. A concrete example has been worked out in Fig. 12.

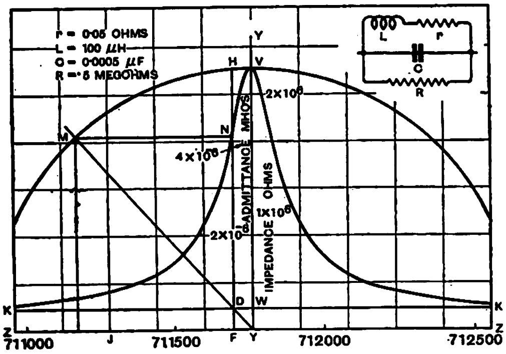


Fig. 12.

Although the development of this construction may seem a trifle involved, it should be noted that the use of it in practice should be quite a simple matter requiring the calculation of three quantities and the drawing of two parallel straight lines and a semi-circle. Thenceforward the construction is an automatic process. The three quantities required are:

(1) f_0 the resonant frequency $= \dfrac{1}{2\pi\sqrt{LC}}$

(2) The quantity $\dfrac{r}{L^2\omega_0^{\,2}} + \dfrac{1}{R}$ and

(3) Its inverse.

It should be noted that (2) is the admittance of the circuit at resonance. And since at resonance

$$\omega_0^{\,2} = \frac{1}{LC}$$

$$\frac{r}{L^2\omega_0^{\,2}} = \frac{r}{L_2\left(\dfrac{1}{LC}\right)} = \frac{r}{L/C} = \frac{Cr}{L}$$

This is an easy quantity to calculate.

Also (3) is the impedance at resonance. If $1/R$ is small enough to be negligible in comparison with $\dfrac{Cr}{L}$ the impedance at resonance becomes $\dfrac{L}{Cr}$ ohms. This is a useful quantity to memorise.

A similar construction may be developed in like manner for the admittance of a series circuit. Here the quantities required are:

(1) f_0 as before.

(2) The quantity $\dfrac{L}{CR} + r$.

(3) Its inverse,

and the scale of impedance is $4\pi L$ times the frequency scale; when R is so large as to make $\dfrac{L}{CR}$ negligibly small, the impedance at resonance reduces to r ohms.

Book Review.

THE DISCOVERY AND FORMULATION OF A NEW THEORY OF THE GENERATION AND PROPAGATION OF WIRELESS WAVES IN SPACE. By H. R. Khan, pp. vi+95, with 27 Plates. Published by Thacker, Spink & Co., Simla. 7s. 6d.

We find great difficulty in reviewing this book. The author is an enthusiast who has devoted much time and thought to the subject, but who describes the phenomena of electricity and magnetism in a language of his own, which makes it difficult to decide to what extent his ideas are new and to what extent they are the conventional ideas expressed in a different terminology. After trying to follow some parts of his argument we were reminded that "East is East and West is West and never the twain shall meet." His experiments have led him to the discovery "that the *taproot* of wireless phenomena is an *entity* which Providence in His great wisdom has provided for the manifold benefits of mankind. It is this entity which I have termed the 'magneto-electric molecule' which forms one of the several invisible constituents of the atmosphere filling the empty space surrounding the earth." We are also told "that water and moisture render the atmosphere of precisely the correct humidity, thereby making the magneto-electric molecules healthy and vigorous." Living in Glasgow we were specially interested in this statement. There is no doubt that our mental picture of magneto-electrical phenomena is largely conventional, but we doubt very much whether we should gain in any way by substituting Mr. Khan's conventions for those with which we are more familiar.

G. W. O. H.

System for Combating Effects of Static.

By E. A. Tubbs.

THE Federal Telegraph Co. of San Francisco, California, maintains a commercial system of wireless telegraphy between the principal cities on the Pacific coast. This service is in direct competition with the Western Union and the Postal telegraphic companies, the two main telegraph systems in the United States. Because of the strong competition it is absolutely necessary that a fast, accurate and reliable service should be available to the public.

For this purpose the company's receiving stations are equipped with some very novel devices; one of the most interesting of which is a system for reducing the effects of static and other undesirable disturbances.[1]

The principle of this static eliminator is shown schematically in Fig. 1. This circuit will be recognised as that of the Carson balanced modulator, which is extensively used in carrier current systems (wired wireless) and in the transatlantic telephone.

In the figure, *V* represents some form of an adjustable oscillator, such as an oscillating valve. Let us first see what will happen if we disconnect this oscillator and then tune the antenna circuit *A* to some desired signal. This incoming signal will be transferred to the inductance *S*, which is tuned to it by the condenser C_2. Therefore, the grids of the two valves 1 and 2 will receive this signal E.M.F. in the same phase and the currents in the two anode circuits will also be in phase. That is to say that if at any given instant the signal current in the anode circuit of valve 1 is flowing from the H.T. battery up through the primary P_1 to the anode A_1, the signal current in the anode circuit of valve 2 will be flowing from the H.T. battery down through the primary P_2 to the anode A_2. Thus it will be seen that the signal current in P_1 and P_2 will neutralise one another and there will be no signal current introduced in the secondary S_1.

Now if we connect the oscillator *V* we will see that it will place a negative potential on the grid of one valve at the same instant that it places a positive potential on the grid of the other valve. This will unbalance the system, because it will let more signal current flow in one of the primaries, P_1 or P_2, than in the other, and when this happens it will be seen that P_1 and P_2 will no longer neutralise one another and signal energy will be transferred to the secondary S_1. Consequently if we adjust the oscillator *V* so that it differs from the frequency of the incoming signal by, say, 1,000 cycles, we will obtain a beat note of 1,000 cycles in S_1, which will be modulated in accordance with the received signal. If the received signal be telephony, then *V* should be adjusted to produce beats of an inaudible frequency, say, for example, 45 kilocycles, in which case the system could be used as the first detector of a superheterodyne receiver.

Now it is a known fact that in heterodyne reception, if the amplitude of the local oscillator is less than that of the incoming

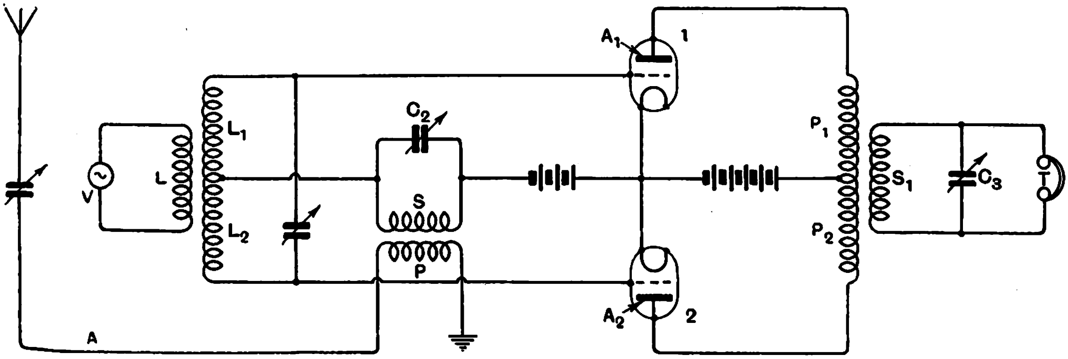


Fig. 1.

---

[1] U.S. Patent No. 1,459,306 issued to Dr. McCaa.

signal, the amplitude of the resultant beat note will be more or less proportional to the local oscillator. Therefore, by adjusting the coupling between L and the two secondaries L_1 and L_2, an adjustment can be found where any interference that is introduced into S_1 will never be louder than the desired signal.

Those of us who have hastened the appearance of grey hairs by the hours on end that we have spent trying to read signals during periods of heavy static, know that static does not really become very troublesome in aural reception until it is a number of times stronger than the signal. Consequently, although the static is only reduced to the same strength as the signal, one gets the impression that it has been relegated into the background and the signal seems to stand out free from interference.

In actual practice this form of static eliminator has proven much more effective in dealing with the crash and click forms of static than with the grinder type.

APPENDIX.

Let us assume that the current and voltage relations of a three-element tube are expressed by the following simplified tube equation:

$$I_A=K[(E_A+\mu E_c)^2+2(E_A+\mu E_c)\mu e+\mu^2e^2] \quad .. \quad (1)$$

where:

I_A =Output or anode current.
K =a constant depending on the tube structure.
E_A =H.T. battery voltage.
μ =Amplification factor of valve.
E_c =C battery or grid bias voltage.
e =any external input potential.

If now we assume that K, E_A, μ, and E_c are held constant, during the operation of the valve, then the first term, $(E_A+\mu E_c)^2$, will represent a steady direct current in the valves output, which will be suppressed by the transformer, P_1, P_2 and S_1. Therefore we may write:

$$I_A=K[2(E_A+\mu E_c)\mu e+\mu^2e^2] \quad .. \quad (2)$$

For purposes of simplification let:

$$2K(E_A+\mu E_c)\mu=D$$

and

$$K\mu^2=C.$$

Then we will have:

$$I_A=De+Ce^2 \quad .. \quad .. \quad (3)$$

Now let us represent the potential, due to the local oscillator, across L_1 by: $+V \sin \omega t$, and across L_2 by: $-V \sin \omega t$, where $V=$ maximum amplitude and $\omega=2\pi$ times the frequency. And similarly let: $S \sin qt$ represent the signal potential across the circuit S, C_2, q being equal to 2π times the signal frequency. The potential applied to the valve 1 will be:

$$e=S\sin qt+V\sin \omega t \quad .. \quad (4)$$

And to the grid of valve 2:

$$e=S\sin qt-V\sin \omega t \quad .. \quad (5)$$

Now substituting (4) and (5) into our tube equation (3) and expanding, we find that the current in the anode circuit of valve 1 will be:

$$I_A=+DV\sin\omega t+DS\sin qt-\frac{CV^2}{2}\cos 2\omega t-\frac{CS^2}{2}\cos 2qt+\frac{CV^2}{2}+\frac{CS^2}{2}+CVS\cos(q-\omega)t-CVS\cos(q+\omega)t \quad .. \quad (6)$$

And similarily for valve 2:

$$I_A=-DV\sin\omega t+DS\sin qt-\frac{CV^2}{2}\cos 2\omega t-\frac{CS^2}{2}\cos 2qt+\frac{CV^2}{2}+\frac{CS^2}{2}-CVS\cos(q-\omega)t+CVS\cos(q+\omega)t \quad .. \quad (7)$$

Because of the fact that the two primaries P_1 and P_2 are opposing each other, we must subtract (6) and (7) in order to obtain the resultant current induced into S_1. Therefore:

$$I_{S_1}=\underbrace{2DV\sin\omega t}_{\text{1st term.}}+\underbrace{2CVS\cos(q-\omega)t}_{\text{2nd term.}}\underbrace{-2CVS\cos(q+\omega)t}_{\text{3rd term.}} \quad .. \quad (8)$$

The first term will be seen to represent an amplification of the oscillator frequency. The second term represents a beat note which is equal to the incoming signal frequency minus the oscillator frequency. This is the frequency which will be heard in the telephones T. The third term represents the sum of the incoming signal frequency and the oscillator frequency, and is obviously of such a high frequency that it can be neglected.

The Use of Alternating Current for Heating Valve Filaments.

By C. W. Oatley, B.A.

Introduction.

DURING the past year great interest has been aroused in this country by the introduction of valves with indirectly heated cathodes for use with A.C. filament supply. It is, therefore, of interest to enquire why such valves should be necessary; in other words, to ask why A.C. cannot be used to heat the filaments of ordinary valves in which the filament is also the cathode. It is well known that when an attempt is made to do this, an audio-frequency note, due to the A.C. mains, is produced in the loud-speaker. There are four ways in which this note might be produced, viz.:—

(1) By direct coupling between leads carrying the alternating filament current with leads connected to grid and anode circuits.

(2) By coupling inside the valve.

(3) By reason of the fluctuations of filament temperature and therefore of filament emission due to the alternations of the current.

(4) By reason of the fact that, since for any one valve the grid circuit can only be connected to the filament at one point, the potential of the grid with respect to other points of the filament varies with time, the magnitude of this variation being equal to twice the amplitude of the filament voltage drop from the point considered to the point at which the filament is connected to the grid circuit.

Of these four effects (1) and (2) will not be considered here, since (1) can be made negligibly small by careful design, while (2) is present in "indirectly heated cathode" valves as well as in ordinary valves. We proceed, therefore, to a more detailed consideration of (3) and (4).

Variation of Filament Temperature.

Let the filament be heated by a current $I \cos \omega t$ and let its absolute temperature at any instant t be θ. Further, let θ_s be the correct running temperature for the filament in question—*i.e.*, the temperature at which it would be run if heated by direct current.

We make the following assumptions:—

(*a*) That the radiation of heat from the surface of the filament obeys Stefan's Law. This assumption is not really necessary, since the final result will be practically the same so long as the rate of loss of heat is proportional to $a\theta^{\psi}$ where a and ψ are constants and ψ is approximately equal to 4.

(*b*) That the variation of temperature is small. This assumption is justified by the fact that we are trying to find the conditions which will make the variation small, since a large variation would render the valve unsuitable for use in a wireless set.

(*c*) That the resistance R of the filament remains constant. This follows from (*b*).

Then rate of supply of heat to the filament

$$= I^2R \cos^2 \omega t \text{ watts}$$

$$= \frac{I^2R}{J} \cos^2 \omega t \text{ calories per sec.,}$$

where J is Joule's equivalent (4.18 Joules per calorie).

This heat is expended in two ways, viz.:—

(1) By raising the temperature of the filament.

(2) By radiation.

If a quantity of heat dQ causes a rise of temperature $d\theta$, we have

$$dQ = c\,d\theta$$

where c is the thermal capacity of the filament.

$$\therefore \quad \frac{dQ}{dt} = c\frac{d\theta}{dt}$$

= rate at which heat is being absorbed to increase the temperature of the filament.

If ρ is the rate of loss of heat by radiation, we have by Stefan's Law

$$\rho = a\,(\theta^4 - \theta_0{}^4)$$

where θ_0 is the temperature of the enclosure surrounding the filament and a is a constant. Since $\theta_0{}^4$ will be negligible compared with θ^4 we may write

$$\rho = a\theta^4$$

$$\therefore \quad \delta\rho = 4a\theta^3 . \delta\theta$$

Since θ is never very different from θ_s we may write

$$\begin{aligned}\rho &= a\theta_s{}^4 + 4a\theta_s{}^3\,(\theta - \theta_s)\\ &= 4a\theta_s{}^3\theta - 3a\theta_s{}^4\end{aligned}$$

Equating the rates of gain and loss of heat:

$$c\frac{d\theta}{dt} + 4a\theta_s{}^3\theta - 3a\theta_s{}^4 = \frac{I^2R\cos^2\omega t}{J}.$$

This may be written:

$$c\frac{d\theta}{dt} + 4a\theta_s{}^3\theta = 3a\theta_s{}^4 + \tfrac{1}{2}\frac{I^2R}{J} + \tfrac{1}{2}\frac{I^2R}{J}\cos 2\omega t.$$

Let

$$\frac{4a\theta_s{}^3}{c} = A, \quad \frac{3a\theta_s{}^4}{c} = B, \quad \frac{\tfrac{1}{2}I^2R}{cJ} = D.$$

Multiply through by ϵ^{At} and integrate

$$\theta\epsilon^{At} = \frac{B+D}{A}\epsilon^{At} + \epsilon^{At}D\left[\frac{2\omega\sin 2\omega t + A\cos 2\omega t}{4\omega^2 + A^2}\right] + \kappa,$$

where κ is the constant of integration.

Rewriting:

$$\theta = \frac{B+D}{A} + \frac{D}{\sqrt{4\omega^2 + A^2}} . \sin\,(2\omega t + \phi) + \kappa\epsilon^{-At},$$

where

$$\tan\phi = \frac{A}{2\omega}.$$

The term in κ will decrease with time and will be negligible when the filament has reached the steady state—in practice a few seconds after switching on the current. Thus finally

$$\theta = \frac{B+D}{A} + \frac{D}{\sqrt{4\omega^2 + A^2}}\sin\,(2\omega t + \phi) \quad .. \quad (1)$$

The mean temperature $\dfrac{B+D}{A}$ may be equated to θ_s, so that

$$\frac{3a\theta_s{}^4 + \tfrac{1}{2}\dfrac{I^2R}{J}}{4a\theta_s{}^3} = \theta_s,$$

whence

$$a = \frac{I^2R}{2\theta_s{}^4J}.$$

If i is the R.M.S. value of I, we have

$$a = \frac{i^2R}{\theta_s{}^4J} \quad .. \quad .. \quad (2)$$

as is otherwise obvious.

The magnitude of the maximum variation of temperature from the mean value θ_s is

$$\frac{D}{\sqrt{4\omega^2 + A^2}} \quad .. \quad .. \quad (3)$$

It will be shown later that A^2 is, in general, negligible compared with $4\omega^2$, so that (3) reduces to

$$\frac{D}{2\omega} \quad .. \quad .. \quad .. \quad (4)$$

From (2)

$$D = \frac{a\theta_s{}^4}{c} \quad .. \quad .. \quad (5)$$

Thus for a given frequency the temperature variations are proportional to the fourth power of the mean temperature and inversely proportional to the thermal capacity of the filament.

For given values of c *and* θ_s *the variations are inversely proportional to the frequency of the heating current.*

Numerical Data.

The following numerical data refer to a thoriated tungsten filament. The first five columns of the table give the filament current (in amps.), voltage (in volts), power (in watts), length (in cms.), and radius (in cms.), respectively. The values are obtained from typical valves of this type, except that, in the case of the filament length a small estimated allowance has been made for the cooling of the filament by the support wires. Assuming the specific gravity of the filament to be 18.8 and its specific heat .033, we can calculate its thermal capacity c from its known dimensions. To calculate A we note from (5) that $D = \frac{a\theta_s^4}{c}$, while $A = \frac{4a\theta_s^3}{c}$.

$$\therefore \qquad A = \frac{4D}{\theta_s}.$$

In the present case we take $\theta_s = 1750°$ K. If we further assume that the frequency of the A.C. supply is 50 cycles per second, we have $\omega = 2\pi f = 314$. Whence we see in all cases that A^2 is negligible compared with $4\omega^2$.

Thus the amplitude of the temperature fluctuation is $\frac{D}{2\omega}$, and values of this quantity are given in the last column of the table.

In Fig. 1 the values of $\frac{D}{2\omega}$ are shown plotted against i_f. Here it is seen that, from the point of view of temperature fluctuation, nothing much is to be gained by using filaments taking more than half an ampere. There is, however, another point to be considered. Under normal working conditions the plate current of a valve is limited by space charge and is only a fraction of the total emission current of which the filament is capable. Therefore, unless the magnitude of the plate current approaches that of the emission current, the former will be almost independent of the latter. The use of large filaments is therefore advantageous in that these have greater emission than small filaments and therefore less tendency to saturate. This is especially true of power valves where the plate current is much greater than in other valves.

TABLE 1.

i_f amps.	v_f volts.	i_f, v_f watts.	l cms.	r cms.	c gm. cals.	D	A	$\frac{D}{2\omega}$ °K.
.1	3	·3	1.6	.001	3.16×10^{-6}	23×10^3	52	34
.12	5	.6	3.5	.0012	10.0	14	33	23
.25	5	1.25	4.8	.002	38.0	7·9	18	12
·4	6	2.4	6.5	.0028	101.0	5·7	13	9.1
·95	6	5·7	7·5	.005	371.0	3·7	8.4	5·7

Variation of Effective Grid Potential.

In order to calculate the consequences of this effect, we make the assumption that the characteristic curve for an infinitesimal element of the filament considered alone is of the same form as the characteristic for the whole filament. If we are dealing with a curved portion of the characteristic the mathematical expression for the curve will not be quite the same in the two cases, but the actual curves will appear very similar. We will define the infinitesimal characteristic to be that curve which is represented by the equation

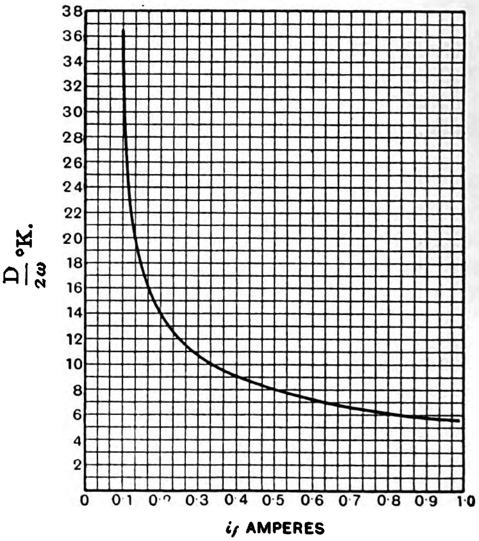


Fig. 1.

$$di_a = f(v_a + \mu_1 v_g) \, . \, dx,$$

where di_a is the plate current due to an element dx of the filament, v_a and v_g are the anode and grid potentials with respect to the element considered, and μ_1 is the infinitesimal amplification constant which need not necessarily have the same value as the ordinary amplification constant. Our assumption is that μ_1 and the function f are the same for all elements of the filament. If we know the form of the function f we can obtain the equation of the ordinary characteristic by integration over the whole filament. In general, f is not a simple function, and we shall consider only two special cases.

Case (*a*). When we are working on a straight portion of the infinitesimal characteristic we may write

$$di_a = \frac{v_a + \mu_1 v_g + \kappa}{\rho_1} \, . \, dx,$$

where ρ_1 is the infinitesimal slope resistance.

Let us suppose that the filament is of length l, and that the voltage applied to it is $E \sin \omega t$. Also that the grid and anode circuit returns are connected to the filament at a point distant b from one end. Then if v_{a_0} and v_{g_0} are the anode and grid potentials with respect to this point, we have for any element of the filament distant x from the end which we are taking as origin

$$di_a = \frac{1}{\rho_1}\Big[(v_{a_0} + \mu_1 v_{g_0} + \kappa) + \frac{E \sin \omega t}{l}(1 + \mu_1)(x - b)\Big] dx.$$

Integrating with respect to x

$$i_a = \frac{1}{\rho_1}\Big[(v_{a_0} + \mu_1 v_{g_0} + \kappa)\, l + \frac{(1 + \mu_1)}{l} E \sin \omega t \, . \left(\frac{l^2}{2} - bl\right)\Big].$$

Therefore, in general, there will be an alternating component in the plate current, but this component will disappear if $b = \frac{l}{2}$, *i.e.*, if we connect the grid and anode returns to the centre of the filament. In practice, of course, the same result is achieved by placing a potentiometer across the filament and connecting to the mid-point of this. It should thus be possible to eliminate hum when A.C. is used on the filament if the valve is used on a straight portion of the characteristic; that is, if it is used as an amplifier.

There is, however, another effect which must be considered in this case. Suppose that the infinitesimal characteristic is linear and without grid current only from $v_g = p$ to $v_g = q$. Then, if the filament is heated by a direct current of voltage V, the permissible grid swing on the complete characteristic will be $(p - q) - V$ (assuming $p > q$). If, however, the filament is heated by A.C., the R.M.S. voltage of which is V, then with the centre-tapped potentiometer arrangement the permissible grid swing will be $(p - q) - \sqrt{2} \, . \, V$. The use of A.C. thus tends to reduce the permissible grid swing. This reduction would probably not be serious in the case of a power valve, but might be so in the case of a resistance coupled amplifier where the available grid swing is already small owing to the fall of H.T. voltage in the anode resistance.

Case (*b*). When we are not working on a linear portion of the infinitesimal characteristic. This case covers the operation of detector valves. A complete theory would be complicated, but the chief results can be obtained by a consideration of an anode bend detector for which the infinitesimal characteristic is parabolic in form. With the previous notation

$$\begin{aligned} di_a &= \frac{dx}{\rho_1}(v_a + \mu_1 v_g + \kappa)^2 \\ &= \frac{dx}{\rho_1}\Big[(v_{a_0} + \mu_1 v_{g_0} + \kappa) + \frac{E \sin \omega t}{l}(1 + \mu_1)(x - b)\Big]^2 \\ &= \frac{dx}{\rho_1}\Big[(v_{a_0} + \mu_1 v_{g_0} + \kappa)^2 + 2(v_{a_0} + \mu_1 v_{g_0} + \kappa)\frac{E \sin \omega t}{l}(1 + \mu_1)(x - b) \\ &\qquad + \frac{E^2 \sin^2 \omega t}{l^2}(1 + \mu_1)^2 (x - b)^2\Big]. \end{aligned}$$

Integrating with respect to x

$$\begin{aligned} i_a = \frac{l}{\rho_1}\Big[&(v_{a_0} + \mu_1 v_{g_0} + \kappa)^2 + 2\frac{E \sin \omega t}{l}(v_{a_0} + \mu_1 v_{g_0} + \kappa)(1 + \mu_1)\left(\frac{l}{2} - b\right) \\ &+ \frac{E^2 \sin^2 \omega t}{l^2}(1 + \mu_1)^2\left(\frac{l^2}{3} - bl + b^2\right)\Big]. \end{aligned}$$

The expression for the plate current thus contains two alternating components, one having the same frequency as the filament supply, and the other double this frequency. (This follows from the fact that $2 \sin^2 \omega t = 1 - \cos 2\omega t$). It is possible to find a value of b (real or imaginary) for which either of these terms will vanish, but both will not vanish for the same value of b.

In general, when the infinitesimal characteristic is of a less simple form, the plate current will contain a fundamental A.C. component and a series of harmonics, and it will not be possible to find a value of *b* for which more than one of these terms vanishes at the same time. Thus A.C. is not suitable for heating the filaments of detector valves when anode bend rectification is employed. The case of grid rectification has not been worked out, but it is reasonable to assume that similar results would be obtained. The fact that A.C. has sometimes been used to heat detector valve filaments without producing noticeable hum in the loud-speaker is probably due to low frequency cut-off in the loud-speaker.

Conclusions.

From the foregoing it appears that indirectly heated cathode valves have a definite place in the detector stage, but it is not obvious that they possess any advantages over ordinary valves as amplifiers. The fact that ordinary valves have not been more extensively used with A.C. in the filament is probably due to (*a*) the high price of suitable valves, and (*b*) the much better mutual conductance of indirectly heated cathode valves.

The high price of valves with heavy filaments, *e.g.*, valves of the L.S.5 type, is not due to any difficulty in introducing heavy filaments into the valve, but to the fact that, being designed to withstand high plate voltages, they must be " bombarded." There is no reason why " gettered " valves of the same dimensions should be any more costly than the smaller receiving valves.

The superiority of indirectly heated cathode valves over ordinary valves in the matter of mutual conductance is chiefly due to the much greater filament power consumption of the former. It may be thought that this statement is not borne out by the characteristics of valves of the L.S.5 type, but it must be remembered that since these valves are designed to withstand high plate voltages, their electrode clearance distances are greater than would otherwise be necessary. It seems probable that a 6 volt 1 amp. coated filament valve could be designed to withstand not more than 150 volts plate voltage and to have a mutual conductance as high as an indirectly heated cathode valve with an equal filament power consumption.

The foregoing remarks, of course, do not take into account the ease with which the two types of valve may be introduced into an existing receiver which was not specially designed to use A.C. for filament heating.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

On the Equivalent Inductance and Capacity of an Aerial.

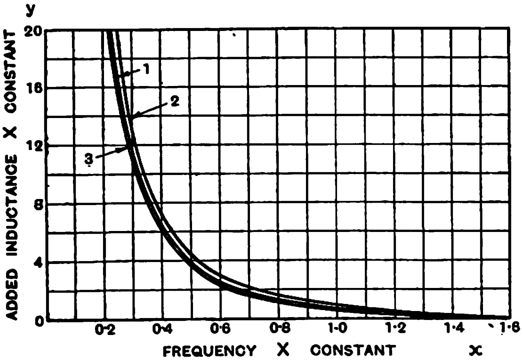
To the Editor, E.W. & W.E.

SIR,—Professor Howe very kindly allowed me to see an advance copy of his editorial for June in which he advocates different values for the equivalent inductance and capacity of an aerial from those which I have given on p. 55 of " Wireless Principles and Practice." As Professor Howe very rightly points out, the equivalent inductance L_0 and capacity C_0 must be such that the square root of their product leads to the same frequency as the natural frequency of the aerial, and also that the " stiffness " of the equivalent circuit must be the same as that of the aerial. A circuit may be considered as equivalent to an aerial circuit when the insertion of an inductance into the equivalent circuit produces the same change in frequency as it does when inserted into the aerial circuit. This is the practical test advocated by Professor Howe in the first paragraph of his editorial.

Professor Howe's values for L_0 and C_0 are $\frac{hL}{2}$ and $\frac{8hC}{\pi^2}$ respectively, where L and C represent the inductance and capacity per unit length of the aerial of height h. The values of L_0 and C_0 on p. 55 of " Wireless Principles and Practice " are (using the present nomenclature) $\frac{hL}{2.46}$ and hC. Thus the two suggested equivalent circuits agree in their natural frequencies since the two sets of values have the same product, but the circuits differ in " stiffness " because the quotients of the two sets of values differ. Taking the " stiffness " to be proportional to $\sqrt{L_0/C_0}$, Professor Howe's equivalent circuit has a " stiffness " proportional to $\sqrt{\frac{hL}{2}\Big/\frac{8hC}{\pi^2}}$ or to 0.786 $\sqrt{L/C}$, whilst my result leads to a " stiffness " proportional to $\sqrt{\frac{hL}{2.46}\Big/hC}$ or to 0.638 $\sqrt{L/C}$.

The method by which Professor Howe obtained his result involves the assumption that the added inductance is *very small* compared with the aerial self inductance, and consequently the resulting change in frequency is correspondingly small compared with the natural frequency. The values of L_0 and C_0 so obtained cannot, therefore, be expected to yield reliable frequency values when the resulting equivalent circuit has a *large* inductance added to it. In the test of equivalence outlined at the beginning of the editorial (p. 297, line 16), and in the first paragraph of this note, no statement occurs to the effect that the added inductance must be very small. Furthermore, in practice, it may be many, many times larger than the self inductance itself. It is shown in the accompanying graph that, as a consequence of the assumption made by Professor Howe, his equivalent circuit fails when tested as advocated above. In fact, the values of L_0 and C_0 which he gives can only be considered as equivalent for the very limited range when the added inductance is practically negligibly small compared with the aerial self-inductance or with the ordinary loading inductances usually employed for tuning aerial circuits.

Turning now to Professor Howe's criticism of my values, he states that the approximation by which I obtain an "erroneous" result is in neglecting the terms $\left(\frac{\omega^2h^2LC}{15} + \text{etc.}\right)$ in the expansion of $\cot(\omega h\sqrt{LC})$. As a matter of fact, I neglect none of these terms. Had they been neglected, the equivalent inductance L_0 would have been equal to $hL/3$ and not $hL/2.46$. The approximation involved, however, lies, not in neglecting the terms, but in including them all as part of the ***inductance***, when actually they contain capacity reactance components. Nevertheless, this procedure is fully justified because the resulting equivalent circuit is found, when tested by the method of adding inductance, to give frequency values which differ from the theoretical values by negligibly small amounts for all magnitudes of added inductance up to, at least, twenty times as big as the aerial self-inductance.



Curve 1.—Theoretical Formula.
Curve 2.—Howe's Formula.
Curve 3.—Palmer's Formula.

Curve *I* shows the resonant frequency resulting when a given inductance L_x is added as a loading coil in the aerial circuit itself. The curve is calculated from the reactance formula:

$$\omega L_x - \sqrt{L/C}\cot\omega h\sqrt{LC}$$

which equals zero for the resonant frequency, with the result

$$\frac{L_x}{hL} = \frac{\cot\omega h\sqrt{LC}}{\omega h\sqrt{LC}}$$

$$\text{or}\quad y = \frac{1}{x\,.\tan x} \quad \cdots \quad \cdots \quad (1)$$

where y is proportional to the added inductance and x is proportional to the frequency.

When the same inductance is added to Professor Howe's equivalent circuit, we get:

$$\omega = 1/\sqrt{(hL/2 + L_x)8hC/\pi^2}$$

$$\text{or}\ y = \frac{1.233}{x^2} - 0.5 \quad \cdots \quad \cdots \quad \cdots \quad (2)$$

From the equivalent circuit given in "Wireless Principles and Practice":

$$\omega = 1/\sqrt{hL/2.46 + L_x)hC}$$

$$\text{or}\ y = \frac{1}{x^2} - 0.406 \quad \cdots \quad \cdots \quad \cdots \quad (3)$$

Equations (1), (2), and (3) are plotted in curves 1, 2 and 3, respectively, for values of L_x from 0 to 20 times as big as hL. From the fact that curves 1 and 3 practically coincide, it is obvious that formula (3) and the value $L_0 = hL/2.46$, $C_0 = hC$ are not erroneous. On the contrary, these values of L_0 and C_0, when tested as outlined by Professor Howe, are found to approximate very closely to the true equivalent values for the aerial self-inductance and self-capacity, respectively.

L. S. Palmer.

[With reference to the concluding sentence of this letter we would point out that the method outlined by us specified that the inserted inductance or capacity should be small (see p. 298, line 7), but the reader is referred to the editorial note on p. 357 of this issue, where the matter is discussed in further detail.—Ed.]

Retro-action in Amplifiers.

To the Editor, E.W & W.E.

Sir,—I have read with much interest the article by Mr. H. A. Thomas, M.Sc., on Retro-action in Amplifiers, which appeared in the May issue. It might appear, however, from this article that in a radio receiver the maximum gain, due to reaction, is given by

$$E_{\max} = \frac{E_0}{\sin\theta},$$

and that with a given circuit arrangement no further gain can be obtained.

While this is perfectly true if θ is kept arbitrarily constant, it is not a case very likely to occur in practice. In any set at least one tuning control is provided and this can be, and is, employed to vary θ. In fact, the set will not, in general, appear to be tuned to the transmitting station unless θ is zero, when maximum signal strength will be obtained. This will not, of course, be infinite, but the limiting factor would not appear to be the finite value of θ, unless the amplifier is used in a detuned condition.

W. S. Percival.

Dagenham, Essex.

Allocation of European Broadcast Wavelengths —Some New Points of View.

By Siffer Lemoine,

Chief Engineer Swedish Telegraph Administration, Member Technical Committee of L'Union Internationale de Radiophonie.

THE problem of the allocation of wavelengths for the broadcasting stations of Europe has for some considerable time proved a constant source of discussion and the question is, perhaps, more acute than ever at the present time.

The scheme devised at Geneva by *L'Union Internationale de Radiophonie,* which came into operation in November, 1926, and to which most of the broadcasting organisations of Europe have given their adherence, has undoubtedly proved a step in the right direction but, in spite of its defects, it cannot be regarded as representing a final solution to the problem.

Many widely divergent difficulties have hindered the successful execution of the proposals. There are countries and broadcasting organisations who have not conformed to the "Geneva Scheme" and whose stations have been continually changing their wavelengths. These have constituted what might be termed a party of "freebooters of the ether" interfering now with one and now with another of the orthodox stations with results that have naturally been of little service either to themselves or to those affected. Further confusion was also caused by the fact that a number of stations were equipped with old-fashioned installations which were unable to maintain the high degree of accuracy now deemed essential in the maintenance of a constant radio frequency and, indeed, unable to maintain even approximately the wavelengths allotted under the scheme, a difficulty which it is hoped will gradually disappear but of which the effect is at present somewhat annoying. When accurate distribution of wavelengths was first attempted this, more than any other factor, proved the greatest stumbling block, but now it can, to a certain extent, be remedied by fitting one of the wavemeters that have been constructed to meet the requirements of the Union. The need for absolute constancy of radio frequency is incontestable and should be insisted on more than has hitherto been the case either in connection with the reconstruction of old installations or in the erection of new stations.

During the past twelve months it may be said that this phase in the development of broadcasting has mainly been characterised if not by stagnation at least by a reduction in its progress as compared with former years, due to a certain doubt as to the principles on which its future is to rest and an uncertainty as to what is likely to be permissible or practicable as time goes on. Even where the Geneva plan has been accepted it has been, in many cases, with a realisation of its imperfection in its present state and in the hope of a revision in the future.

True, some countries have, within the scope of the agreements now in force and without waiting for forthcoming international regulations, managed to increase the power of their stations, but most countries have adopted a cautious attitude, both as regards extending their power and erecting new installations, having in mind especially the question of the principles that might be laid down on this point by the International Radio Conference held at Washington last autumn.

The Resolutions passed by the Washington Conference, and their significance.

The resolutions passed by the Washington Conference are now known, although there has not yet been time to ratify them. Various wireless services have had their different wavebands allotted — including broadcasting—while the particularly vital question (from the European point of view) of wavelength rights for every country and other principles governing the use of the broadcasting bands has been left open for the present.

It may be said that the result, as far as broadcasting is concerned, has been poorer than had generally been anticipated. Those zones that have now been assigned for the purpose have been extended in so niggardly a fashion that not only has the growth of the number of stations been stunted but a restriction has been practically laid on those that were previously functioning.

Thus, above 1,000 metres, permission has been granted in Europe to use the zone from 1,875 to 1,550 metres, corresponding to 160-194 kilocycles per second, exclusively for broadcasting and from 1,550 to 1,340 metres (194-224 kc/sec), jointly with the air services, but with the proviso that no increase in power may take place so long as disturbances with other traffic may be caused thereby. Below 1,000 metres the limit upwards has been reduced from the present maximum of 600 metres down to 545 metres, while the lower limit has been maintained at 200 metres—corresponding to the kilocycle numbers 550 to 1,500—with the exception of 220 metres (1,365 kc/sec.), which has been allotted exclusively for maritime requirements.

An examination into the significance of these proposals shows that in a way broadcasting finds itself in a more embarrassed situation than before. From having previously been comparatively free from control it has now been confined within a zone amounting in all to no more than 1,014 kilocycles, and this too without taking account of the 220 metres wavelength allotted to shipping as mentioned above, which will in practice not mean a fixed frequency but a band of considerable breadth. The frequency zones that broadcasting has been granted in addition, comprising lower wavelengths from 50 metres downwards, are at present of no very great importance for the development of normal broadcasting in Europe and in this connection are therefore disregarded.

On the other hand, the resolutions passed in Washington imply a distinct gain, in so far as we are now actually able to say what lines are to be followed. From the point of view of principle, this is more or less of secondary importance, as all countries have conformed to the regulations in question and thus one and all have to come in line with the new order. The resolutions will come into force on the 1st January 1929, except those affecting the higher wavelength zone for broadcasting, for the enforcement of which a further respite of one year has been granted.

The wavelength distribution for which the Geneva plan has been worked out comprises only the zone from 200 to 600 metres, whereas stations working on other wavelengths have had to rely on their right of priority, which in fact has as a rule been respected. This might have been satisfactory enough at a time when there were no restrictions as to wavelength either upwards or downwards, but as soon as the Washington resolutions come into force, matters will be very different. It is obviously no longer either reasonable or fair to regard the two bands as separate, so that a few privileged countries, actually not more than seven, solely on grounds of priority, may lay claim to the higher wavelengths, while the lower band is allotted on a basis that is independent of the former and to which all are alike entitled. When the allocation is made all frequencies should be included and the question regarded as a whole.

Area and population as principles governing the distribution of wavelengths.

Before proceeding further, mention should be made of the principles laid before the Technical Committee of the Union Internationale by the author at the time—principles which, with certain modifications, formed the basis of the distribution now in force. The first of these contentions was that the number of wavelengths which a country is entitled to possess should be in a fixed proportion to the area of the country. The second proposed that consideration should be given to the size or density of the population.

As regards the first of these principles, it must still be considered to have full force, It may be assumed with approximate accuracy that a broadcasting station of a certain power and with normal equipment has the same range, regardless of the country in which it is erected—there are certainly some exceptions to this, such countries as, for instance, Norway and Switzerland, and part of Sweden, with very mountainous and wooded terrain, are at a disadvantage, whereas on the other hand, the conditions in Holland and Denmark are more favourable than the average. If we take as our basis the idea that every individual, to whatever country he belongs, shall be equally privileged as regards the possibilities of listening-in, the problem of wavelength would be solved simply enough—viz., allotted in proportion to the area of each country. For reasons which will be more closely dealt with later on, however, the time has apparently not yet arrived when we can accept this simply and solely as the basis of distribution ; if we are not to lose continuity in the development, we must also give consideration to other factors.

As to the principle of population, the argument produced at the time in favour of this was that the more densely populated areas were better entitled to be supplied with more convenient means of " receiving " than sparsely populated districts, and in consequence certain countries should be allotted a greater number of wavelengths. It may be remembered in this connection that these proposals were made in 1925, that is to say, at a period when the size of the biggest commercial transmitters existing on the market was at the most 1½ kilowatts. This way of looking at the subject might have been justified at the time by the difficulty of building stations of sufficient power, but nowadays that point of view can hardly be considered tenable, seeing that transmitters of as much as 50 kilowatts and more are now standardised and may be procured at a reasonable price. In certain cases better results and increased efficiency are obtained by the removal of the station to a more suitable locality.

In this connection I venture to quote from the minutes of the meetings of the Union's Technical Committee, held at later dates, a recommendation mentioned in several places and reading as follows : " Fewer stations, greater power "—a principle which is fundamentally quite true and the truth of which, as such, is worthy of being emphasised. It goes without saying that it is in densely populated areas that an outlay of capital for higher-powered transmission will pay best, besides giving the listeners-in within the service area better possibilities of reception, and bringing to the business an increased income from new licence-holders.

Observations on the Question of Modifying the Primary Basis of Distribution.

The question of wavelength distribution must not, however, be viewed merely against a theoretical background ; account must also be taken of the position of the present stage of development. The author does not mean by this that the population principle should at once be entirely eliminated, as in certain countries this would involve too sudden a reversal of conditions. A gradual modification is a matter of minor importance and would not seriously inconvenience the broadcasting organisations affected, but enable them to effect the change gradually and without too much friction.

The primary principle that, according to the author's proposal, should be made the basis of a revised allocation of wavelengths is as follows :—

Every country would obtain the right to a number of wavelengths as corresponding to a function of the country's area and population expressed in percentage, calculated on the basis of area plus one-half the population.

In Table I a summary has been made according to the latest available official statistics on the areas and populations of the countries of Europe, with the exception of Russia and Turkey in Europe. The total area amounts to 5,329,500 sq. kilometres and the population to 36.15 millions. In the last column have been worked out for each country comparative numbers according to the formula $a + \frac{b}{2}$, where a denotes the area and b the population, both expressed in percentage of the total figures.

If we compare the comparative numbers deduced according to this formula with those obtained if the *same* value were given both to area and population, we find that only a few unimportant modifications take place slightly to the disadvantage of small and densely populated countries, while corresponding advantages accrue to states with a large area but comparatively small density of population. I would emphasise the fact that the table may obviously be adapted to admit of such modifications as may be rendered necessary by special requirements, such as, in particular, unfavourable geographical conditions, polylingual nations, etc., and that, conversely, it may be possible to make certain limitations wherever theoretical deductions have produced abnormally high comparative numbers.

TABLE I.

COMPARATIVE NUMBERS FOR WAVELENGTH DISTRIBUTION IN PROPORTION TO SUPERFICIAL CONTENT AREA AND POPULATION.

Country.	Superficial Content (a).		Population (b).		Comparative Numbers.	
	100 sq. Kms.	%.	Mill.	%.	$a + b/2$.	%.
Albania	275	0.52	0.83	0.23	0.635	0.42
Austria	838	1.57	6.58	1.83	2.485	1.66
Belgium	304	0.57	7.87	2.19	1.665	1.11
Bulgaria	1,031	1.94	5.48	1.52	2.700	1.80
Czecho-Slovakia	1,404	2.63	14.24	3.95	4.605	3.07
Denmark	429	0.81	3.42	0.95	1.285	0.86
England	2,448	4.59	45.21	12.55	10.865	7.24
Esthonia	475	0.89	1.12	0.31	1.045	0.70
Finland	3,885	7.29	3.29	0.91	7.745	5.16
France	5,510	10.34	40.74	11.31	15.995	10.66
Germany	4,704	8.82	62.54	17.37	17.505	11.67
Greece	1,270	2.38	6.20	1.72	3.240	2.16
Holland	408	0.77	7.52	2.09	1.815	1.21
Hungary	929	1.74	8.37	2.32	2.900	1.93
Iceland	1,028	1.93	0.10	0.03	1.945	1.30
Ireland	698	1.31	2.97	0.85	1.735	1.16
Italy	3,097	5.81	40.55	11.26	11.440	7.63
Lettland	658	1.23	1.86	0.52	1.490	0.99
Lithuania..	561	1.05	2.23	0.62	1.360	0.91
Luxemburg	26	0.05	0.27	0.07	0.085	0.06
Norway	3,238	6.08	2.77	0.77	6.465	4.31
Poland	3,883	7.29	29.25	8.12	11.350	7.57
Portugal	887	1.66	5.62	1.56	2.440	1.63
Roumania	2,942	5.52	16.98	4.71	7.875	5.25
Spain	4,979	9.34	21.62	6.00	12.340	8.23
Sweden	4,485	8.42	6.07	1.69	9.265	6.18
Switzerland	413	0.78	3.94	1.09	1.325	0.88
Yugoslavia	2,490	4.67	12.49	3.47	6.405	4.27

Wavelength Allocation according to the Geneva Plan.

For the sake of comparison with the calculation, worked out in Table I, of the new figures proposed as a basis for a revised wavelength distribution, there is given in Table II, as a supplement to the above table, a comprehensive table of the Plan now in force. After the introduction of a third factor, borrowed from the official statistical information drawn up by the League of Nations regarding the use of the telephone and the telegraph in each country, it was resolved that a distribution should be made among the different countries in accordance with Table II :—

This table relates only to the exclusive wavelengths, and Russia has here been excluded from the list, that country not having been represented at the Washington Conference and its attitude towards the question being still unknown. If we examine Table II side by side with Table I, we find agreement in the main, but in certain cases there are considerable differences. Thus, some countries have been allotted, on the Geneva Plan, the same number of wavelengths as others whose area is ten times greater. From a purely technical point of view every one must, of course, admit that the situation of the country that has received a less favourable allotment is fairly hopeless as regards the possibility of carrying on effective broadcasting and that, in such cases, justice and equity demand that a change should be made.

TABLE II.

WAVELENGTH DISTRIBUTION ACCORDING TO THE GENEVA PLAN.

Country.	No. of Exclusive Wave-lengths.	Country.	No. of Exclusive Wave-lengths.
Albania ..	1	Italy ..	5
Austria ..	2	Lettland	1
Belgium ..	2	Lithuania	1
Bulgaria ..	1	Luxemburg ..	1
Czecho-Slovakia	3	Norway ..	3
Denmark	1	Poland ..	4
England ..	9	Portugal	1
Esthonia ..	1	Roumania	2
Finland ..	2	Spain ..	5
France ..	9	Sweden ..	5
Germany*	12	Switzerland ..	1
Greece ..	1	Yugo-slavia ..	1
Holland ..	2		
Hungary ..	1		
Iceland ..	—		
Ireland ..	1		

* To be taken 5 in each section.

The Principles for the Mutual Location of the Wavelengths.

The second question of at least equal importance to that of the allocation of the *number* of wavelengths to each country is that of the *mutual location* of stations within the 200–600 metre zone. The number of wavelengths has been based on the principle of a frequency difference between each of 10,000 cycles per sec. Proposals have been brought forward to reduce this difference in order to make room for more stations; it would seem, however, that the time for this has not yet arrived and the present basis of distribution must be maintained for some time longer.

The principles applied in placing the stations have been, in the first place, the so-called polygon procedure, consisting in two stations whose frequencies are of about the same order, being placed at the greatest possible geographical distance apart, as a rule at distances of about 1,000 to 2,000 kms. and, secondly, the acknowledgment of a certain prior right to a previously utilised wavelength. With regard to the polygon method, I shall revert thereto later on in another connection. As to the principle of priority, which should without doubt be given the same value as before, I propose to quote what I wrote on the matter in an earlier report, as follows: "It may be considered reasonable that a station that has for years past been working on one and the same wavelength should be allowed to continue to retain it wherever possible, or, if a change must be made, that this should be done only within such a zone that existing receiving sets within the normal radius of the station need not be altered."

The consequence of this has naturally been that the "better" zone between 300 to 600 metres has been the most sought after and been the first to be utilised, while frequencies below 250 metres have, to a considerable extent, been held as a kind of reserve for future requirements. It may also be regarded as a logical result that countries whose broadcasting has been organised at a later date must in that case be content to use wavelengths within a band that has not previously been occupied.

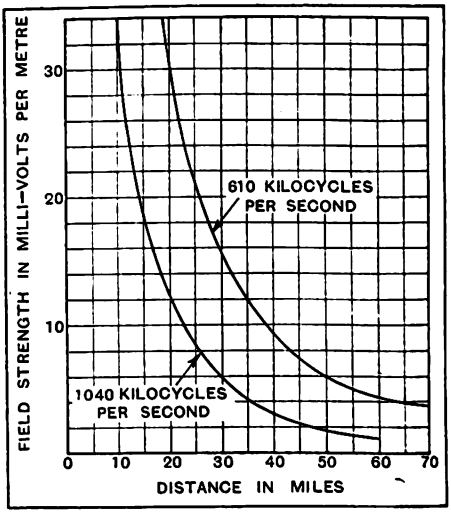


Fig. 1.

Proposal for the Introduction of So-called Wavelength Equivalents.

On the other hand, in the author's opinion, an incorrect method has been employed when, in allotting wavelengths, attention has been paid exclusively to the *number* of wavelengths apart from the question of where they are to be found within the frequency zone, and no consideration has been given to the question of their different service-value. As is well known, a wavelength of 200 metres is, as regards its efficiency, not so desirable as one of 500, wherefore they cannot be compared with one another *qua* wavelengths.

A comparative valuation of different frequencies is justified for two reasons: first, the higher the frequency the greater is the attenuation of a radiated wave; and, secondly, a higher wavelength permits the use of higher masts for the same radiation resistance and consequently gives a greater number of metre-amps. for the same primary power. In consequence of the resolutions passed by the Washington Conference, and since the possibility of a choice of wavelength outside the fixed frequency bands is almost entirely eliminated, the standpoint of equal values is still less justified than before. On the other hand, since it is desirable that the basis of any allocation of wavelengths should be equally applicable to the higher and the lower wavelength zone, the question is whether an acceptable formula can be found for allotting a value to the different frequencies in relation to one another.

Here we have several points of departure to choose from. It is possible to gauge the field-strength at various distances from a given station at different frequencies and when using the same power. Such curves have been published, *inter alia*, by *P. P. Eckersley* in a recent paper read before *The Institution of Electrical Engineers*, from which the illustration (Fig. 1) has been reproduced. Similar results have been obtained in a comparison between measurements of the field-strength from broadcasting stations in Sweden, thus Fig. 2 shows field intensity curves from one and the same station; Fig. 3 similar curves from two different stations, in both cases

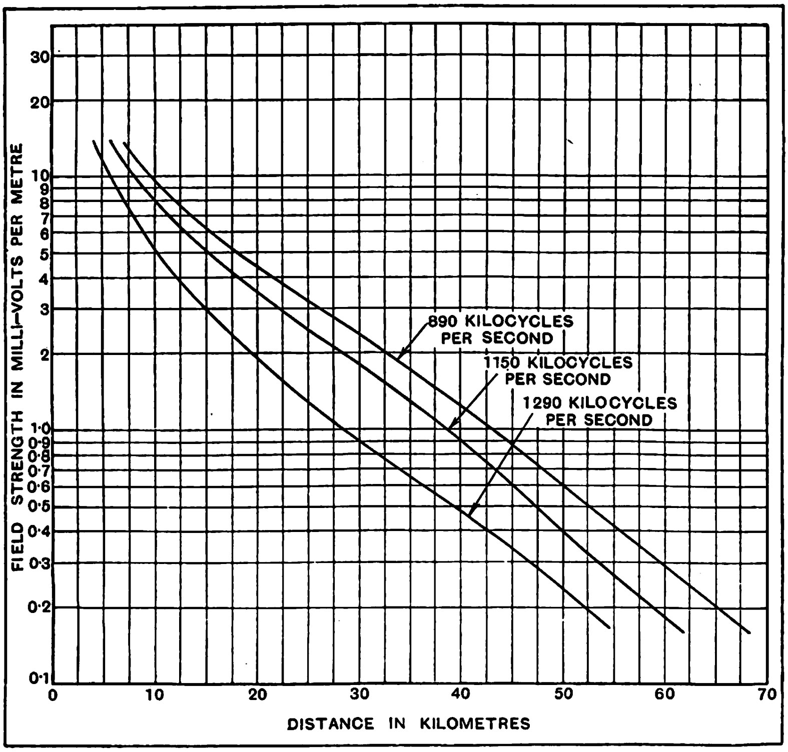


Fig. 2.

with approximately the same aerial output. As the measurements in the latter case were taken over land of varying character—actually more favourable to the short-wave station—no direct comparison can be made, but the example shows clearly that there is no small difference in the efficiency of the wavelengths in question.

The object of reproducing these curves is mainly to show that it is not possible by means of measuring to secure a simple and generally applicable expression for the comparative service value of the wavelengths, chiefly owing to the fact that the field intensity as a rule is dependent on the nature of the ground in each particular case. It seems to be equally improbable to be able to deduce the desired formula on a basis of purely theoretical speculation.

Disregarding therefore the investigations made by the author into the possibilities of using strictly mathematical calculations in the derivation of a suitable formula, the following proposal is submitted: *The service value of one arbitrary wavelength in relation to another within the broadcasting band is calculated as the cube root of the ratio between the inverse values of their frequencies,* this value being hereinafter called the *wavelength equivalent.*

If for this purpose we choose 300 metres, corresponding to 1,000 kc/sec., as a standard, the desired wavelength equivalent equals the cube root of the quotient between 1,000 and the respective kilocycle number and the calculations will then be easy to work out. In Table III are given the wavelength equivalents, first for the band between 160 and 224 kc/sec. for every 10th kilocycle, secondly for the upper frequency-band for every 100th kilocycle, and in Fig. 4 they are further shown graphically as a function of kc/sec.

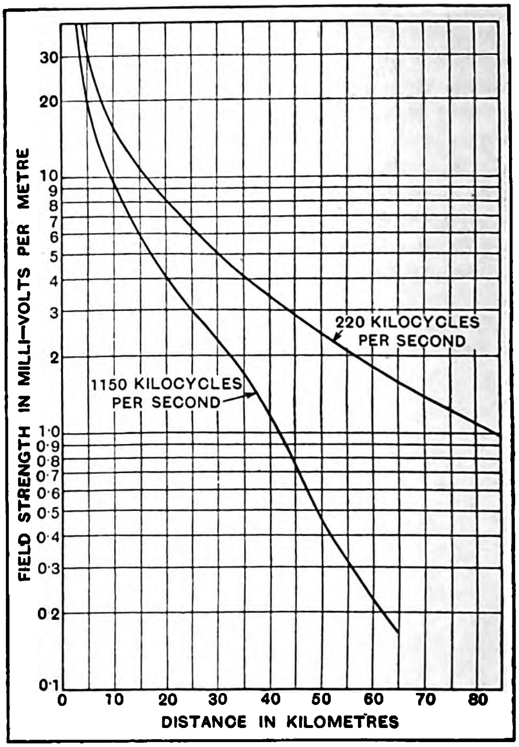


Fig. 3.

This valuation of higher or lower frequency implies that, for instance, a wavelength between 550 and 500 metres would be regarded as having about 40 per cent. greater efficiency than a wavelength of about

TABLE III.

WAVELENGTH EQUIVALENTS FOR DIFFERENT FREQUENCIES.

Frequency in Kc/sec.	Wavelength in Metres.	Wavelength Equivalent.	Frequency in in Kc/sec.	Wavelength in Metres.	Wavelength Equivalent.
162	1,852	1.84	700	428.6	1.13
172	1,744	1.80	800	375.0	1.08
182	1,648	1.76	900	333.3	1.04
192	1,563	1.73	1000	300.0	1.00
202	1,485	1.70			
212	1,415	1.68	1,100	272.7	0.97
222	1,351	1.65	1,200	250.0	0.94
			1,300	230.8	0.92
550	545.6	1.22	1,400	214.0	0.89
600	500.0	1.19	1,500	200.0	0.87

200 metres, and further that the wavelengths within the higher band are calculated, on an average, to be 50 to 60 per cent. more effective than those between 300 and 550 metres.

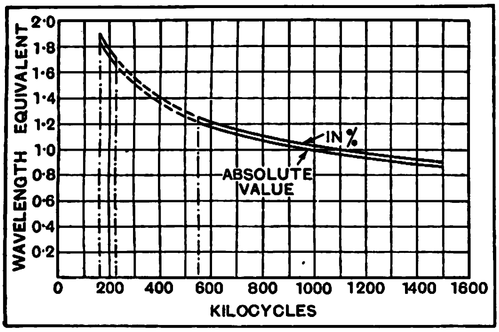


Fig. 4.

If we compare the values of the Table with results obtained by taking measurements, we find that they are throughout a little unfavourable to short-wave stations. It is the view of the author that, to a certain extent, this must actually be the case. The main argument against the introduction of frequency equivalents is that by increasing the power of stations working on lower wavelengths it is possible to counteract the greater attenuation and to obtain an equally long range. This reasoning is correct only within certain limitations. To obtain parity in range between a wavelength of 200 and one of, say, 1,500 metres, would require a power amounting to several hundred kilowatts, with correspondingly heavier establishment and greater running costs. On the other hand, the mathematically less exact agreement and the advantage which the formula gives to the lower frequencies can be compensated without much sacrifice by a smaller increase in the power or often even merely by adopting more suitable arrangements in order to get a better efficiency.

Exclusive and shared wavelengths.

When the above-mentioned allocation of frequencies between 200 and 600 metres was fixed at Geneva, it was decided that the number of so-called exclusive wavelengths should be 83 and the shared waves 16. It seems in this connection that the question of this distribution should also be taken up for renewed discussion.

The reason for the existence of the shared wavelengths was the need in certain countries for utilising a smaller number of transmitting stations with only a local range. This system has for the present been adopted in most countries. In view of the present establishment the shared wavelengths cannot on that account be removed at once without further notice, but there exist strong reasons for restricting the number, say, from 16 to 12, which in all probability could be done without much inconvenience.

The shared wavelengths have been allocated fairly evenly, being distributed over the entire wavelength band, starting at 588 metres, then at 500, 400, 300 metres, and so on, downwards. An alteration in this arrangement might now profitably be made. Since it was originally the intention that those stations working on shared waves were supposed only to possess a local range and consequently to be equipped with transmitters of comparatively small power—this might be put at approximately not more than 200 watts aerial energy or about 100 metre-amps.—there is no reason why one should set apart for this purpose higher wavelengths that are more serviceable for exclusive use; on the contrary, lower wavelengths are even better adapted for that purpose.

A proposal for a new allocation of the common frequencies is made in Table IV in which the scheme now in force is also given for comparison purpose. All the 12 shared wavelengths proposed are placed below 300 metres, viz., three up to each one of the frequencies 1,100, 1,200, 1,350 and 1,500 kilocycles/sec.

By the adoption of this reduction in the number and re-allocating the shared wavelengths: First, restrictions on the zone 500 to 550 kc/sec. are compensated for; the Washington Conference prohibits the use of this zone for broadcasting, certain countries, however, being at liberty, wherever possible, to allocate thereto stations of low power, provided that no interference is caused to commercial services. Moreover, the wavelengths of 500, 400 and 300 metres, which have actually proved not very good for joint use, are released as exclusive.

Finally, the frequencies around 220 metres, which have at the same time been allotted to marine wireless traffic, might perhaps conveniently be used by stations having common wavelengths, in cases where the interference from either side may be expected to be negligible.

TABLE IV.

List of the Present and a Proposal for new Shared Wavelengths.

Present Wavelengths.		Proposed Wavelengths.	
Frequency in Kc/sec.	Wavelength in Metres.	Frequency in Kc/sec.	Wavelength in Metres.
510	588.2	1,090	275.2
520	577.0	1,100	272.7
530	566.0	1,110	270.3
600	500.0		
		1,190	252.1
750	400.0	1,200	250.0
1,010	297.0	1,210	247.9
1,020	294.1		
1,080	277.8	1,350	222.2
		1,360	220.6
1,090	275.2	1,370	219.0
1,100	272.7		
1,180	254.2	1,480	202.7
1,190	252.1	1,490	201.3
		1,500	200.0
1,200	250.0		
1,470	204.1		
1,480	202.7		
1,490	201.3		

Application of the Principle of Wavelength Equivalents.

To return to the discussion on the exclusive wavelengths, it has previously been mentioned that the total range of frequencies available for broadcasting amount in all to 1,014 kc/sec., which, allowing for a difference of 10 kilocycles between stations, corresponds to 103 usable frequencies. After deducting the proposed 12 shared wavelengths there thus remain a total of 91 for distribution amongst all the countries of Europe.

It is proposed that the distribution of these should be carried out on the following principle: *Each country to be allotted that number of frequencies of which the sum of the wavelength equivalents, expressed in percentages, corresponds to the respective comparative numbers given in Table I.*

If we work out the total wavelength equivalents for all frequencies, we obtain, after deducting the shared wavelengths, the number 98.45. From this we must further deduct 1.7 for the big station in Moscow working on about 1,450 metres, which we must take into account for the purposes of this calculation. On wavelengths below 600 metres, on the other hand, there are in Russia at present only a couple of installations of minor importance. The final result will then be 96.75. If, further, we convert the absolute value of each wavelength equivalent in Fig. 4 and express it as a percentage of the total, then the sum of the percentage equivalents of the wavelengths each country is entitled to use will equal the comparative numbers calculated in Table I.

The gist of this is perhaps best explained by means of examples. In the case of most countries the new principle of distribution results in no change. For Great Britain the application of the formula would entail a certain reduction of the wavelengths now provided. Thus, England has, according to Table I, the comparative number 7.24, and with the 10 wavelengths, including Daventry, which are now in use, she would receive an absolute equivalent of 11.27, corresponding in percentage to 11.65. A strict application of the principle would therefore involve a surrender of one or two of the existing lower exclusive wavelengths. The application of the formula would likewise prove disadvantageous to Sweden and Germany, compared with the present arrangement, while on the other hand, Finland, Italy, Norway, Poland, Spain and Hungary, *inter alia*, would find their position improved. (For possible modifications when the formula is brought into effect, see under final observations.)

Group Allocation of Wavelengths instead of the Polygon Method.

As regards the determination of the frequencies that the various stations must use, the author's view is, as already pointed out, that the principle of priority should still be adhered to as far as is feasible when the distribution is made; concerning the application of the polygon method, however, this system might usefully be made the subject of discussion.

As is well known, the radiation from a transmitting station is of two kinds, viz., ground-radiation and space-radiation, of which the former represents the radiation of service to listeners within the normal radius; while the latter as a rule is useful for listeners at very great distances. Experience further goes to show that the space-radiation in the case of the frequencies used in broadcasting returns by reflection to the earth's surface with a maximum of strength at distances of about 1,000 to 2,000 kms., which, when the polygon method is employed, is about equivalent to the distance between two stations of closely related frequencies.

The consequence of this is—and a great many complaints from different quarters testify to the fact—that listeners not infrequently experience great difficulty in distinguishing between the programme of their own station and that of the foreign station next to it in frequency, although it may be remote in point of distance. It is not intended to try in any way to depreciate or disregard the demand for selectivity in receiving sets, but the fact remains that great inconvenience is caused by the present system. There are, for instance, continental stations which, owing to their high power and powerful ether radiation, after nightfall can be heard splendidly in neighbouring countries within the crystal-range of their own local stations, and even on crystal sets employed for the reception of local stations. Moreover, it may be supposed that these interferences will be felt in proportion as the number of higher power stations increases.

One way in which the author considers it possible, at least in part, to eliminate this trouble, is to substitute for the polygon method what may most suitably be termed the " group-allocation " of the wavelengths, which would mean that, *if a country possesses the right to several frequencies, these frequencies should be allotted in groups of three or four adjacent bands.*

In this there are at least two advantages to be gained: first, the broadcasting organisation in each country will itself become responsible for the frequencies within each band being kept constant, which would be quite easy when the stations are subordinate to one and the same authority—at the same time the work of the international wavelength control would be lessened—and if they fail in their efforts, their own listeners and not, as is now the case, listeners outside the country, who have nothing to do with the matter, will be the sufferers. Secondly, many of the disturbing effects of the space-radiation would be eliminated, since they would come within a considerably broader frequency-band, and thus listeners to their own local stations will not be troubled by it to such an extent as at present. And a third advantage is that owners of sufficiently selective sets will be afforded at least as good, if not better, chances of picking up stations over greater distances. Two stations adjacent in frequency already exist in England, namely, Aberdeen and Daventry Experimental (5GB). Whether or not these disturb one another in England I do not know, but that they produce interference on the Continent is an acknowledged fact.

It may be added that, as matters stand to-day, the demand for increased transmitting power is often quite as fully justified by the plea of international competition as by the desire of the station to increase its own range. The former way of viewing the matter, which, of course, does not tend to a sound development of broadcasting, would, if the group-allocation of wavelengths were introduced, have less grounds for justification.

Summary.

The views submitted above regarding a revision of the system now in force for allocating the wavelengths of the European broadcasting stations may be summarised as follows :—

(1) That every country shall have the right to such number of frequencies as corresponds to a function of the country's area and population, expressed as a percentage, for which purpose the first factor is taken as the whole, and the latter as half, the numerical value.

(2) That such right shall involve the necessity, before a certain date to be fixed by the Union or other International Conference, of taking into actual use the frequencies allotted, and if this is not done, then, by agreement, such frequencies may be disposed of in some other way, until the International Radio Conference of 1932 determines otherwise.

(3) That all wavelengths that are available within the frequency-bands fixed by the Washington Conference shall be distributed on a common basis.

(4) That the valuation of different frequencies shall be made by the intro-

duction of so-called "wavelength equivalents" on the basis of the formula here drawn up by the author, calculated, in the manner suggested, as the cube-root of the ratio between the inverse values of their frequencies.

(5) That the number of shared frequencies be reduced, to consist of 12 wavelengths instead of the present 16.

(6) That in the allotment of frequencies to various stations and in the application of the principle of priority investigations be made into the possibility of introducing a certain "group-allocation" instead of the polygon method.

(7) That such deviations from the principles outlined above may be made as special circumstances require.

Final Observations.

Before closing this article I would like to make a few final remarks and observations. First, then, it may be pointed out that the proposals and views submitted above have not been offered with the idea of procuring for my own or any other country greater advantages than those they have previously enjoyed or may be expected to enjoy in the future, but they represent an attempt to deal with relative questions from an international angle. The object, therefore, is primarily that the views here submitted shall form a basis for a comprehensive enquiry and for further discussion of these problems, and contribute towards giving permanent shape to the international system the foundations of which have been laid by the Geneva Union, and thereby conduce to the continued development of broadcasting.

It may also be emphasised that it is not, in the author's opinion, either possible or expedient to bring these proposals into immediate effect on the strict basis of his theoretical deductions, but, on the contrary, common principles of application are inevitably necessary, exceptions, however, being made in cases where they are deemed to be justified.

Broadcasting has not developed uniformly in all countries, nor, of course, is it likely to do so in the future. The suppression of what has once been created in favour of newly arisen demands cannot perhaps be avoided in a number of cases, but, on the other hand, it must be admitted that this cannot be done all in a moment; we must keep pace with the discovery of fresh means for solving the problems that arise. Nor can broadcasting afford to let employable frequencies be kept in reserve for an indefinite period; they must be utilised as and when required (point 2 in the summary). At the same time, it is the author's intention, in this article, to give a comprehensive idea of the prevailing conditions and of the difficulties with which broadcasting, regarded internationally, has at present to contend, and also that any claims that may arise must be considered by everyone in their proper light and adjusted accordingly.

At the meeting of the Technical Committee of the International Union, held in Prague last February, the desire was expressed in several quarters for a revision of the present system with a view to its being brought into line with the resolutions of the Washington Conference.

In submitting this article, with the views on the various problems expressed therein and proposals for their solution, the author ventures to express the lively hope that, as these questions may shortly be expected to be taken up for international discussion, his recommendations may happily serve their purpose.

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

MEASUREMENT OF FADING.—(*Bureau of Standards, Washington,* "Scientific Paper" No. 561).

A record of tests carried out by stations in the United States and Canada, and the conclusions drawn.

THE POLARISATION AND FADING OF SHORT WIRELESS WAVES.—T. L. Eckersley. (Letter to *Nature*, 5 May, 1928, Vol. 121, p. 707).

The effect of the earth's magnetic field in altering the plane of polarisation and producing circular polarisation in a transmitted wireless ray has been fairly fully discussed recently by Nicholls and Shelling and by Appleton. Examples of this effect have been observed at night time when the ray from a vertically symmetrical aerial gives a received ray either partially or wholly horizontally polarised, and consequently an erroneous bearing. The letter describes two sets of experiments carried out in the daytime in which rather more definite indications of these effects were observed on very short waves (from 14 to 50 metres) using a unidirectional receiving aerial consisting of a vertical aerial coupled to a closed loop rotating about a vertical axis. Experiments in April, 1927, with this arrangement showed that on certain occasions, relatively rare but quite definitely established, the received ray was circularly or elliptically polarised. The effect has not been observed on long-distance stations, and appears to be most marked on stations just outside the skip-distance. Five stations giving the effect are mentioned, three being (relatively to the observer) in the sector E. to S.E., the other two being W.S.W. and W. nearly. The first three always showed polarisation in a clockwise direction, the latter two in a counterclockwise. Unfortunately there were no stations to the N. on which to test.

The writer continues: "The explanation is obviously connected with the double refraction suffered by two circularly polarised components of the plane polarised wave emitted; one of the components being more bent than the other, the two will be separated near the edge of the skip-distance where the effect is observed.

"It has not been possible yet to trace the two rays which must pass through a medium of variable electronic density, partly along and partly across the earth's magnetic field, in sufficient detail to account for the difference in direction of rotation of the rays according as they travel eastward or westward. But it might be surmised that at greater distances, that is, well outside the skip-distance, both the rays into which the original plane polarised wave is split will reach the receiver, where they will combine to produce a plane polarised ray, the direction of which will depend on the distance traversed by the ray through the medium and the strength of the magnetic field.

"This resultant direction will vary momentarily with slight changes in the path and the earth's magnetic field (as suggested by Breit), with the result that the vertical field will vary from time to time and produce fading. But fadings from this cause, which is due to a bodily rotation of the electric vector, will produce opposite effects on a vertical and horizontal aerial perpendicular to the ray. In fact the fading on one will be the inverse of the fading on the other, for when the vertical electric force is a maximum, the horizontal force is zero and *vice versa*. Experiments made recently confirm this view, at least in certain cases. In Fig. 1 (not abstracted) simultaneous fading records taken on a horizontal and vertical aerial are shown, and it is clear at a glance that these are opposite in phase.

"The observations were made on *PQW*, a beam station at Lisbon, and many more records showing the same characteristics have been taken. Apart from the theoretical interest, these results have great practical value in devising systems which will eliminate, or at least reduce, fading.

"Whether all short wave fading is of this type remains to be seen, but further experiments seem to show that this is not the only type of fading."

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

EINIGE UNTERSUCHUNGEN ÜBER DEN BLITZ (Some investigations into Lightning-flashes).—L. Binder. (*E.T.Z.*, 29 March, 1928, V.49, pp. 503-507.)

From thermal effects the current-strength of very powerful flashes is reckoned at $9{,}500 : \sqrt{t}$ (for example, if $t = 1/100$ sec., $I = 95{,}000$ amperes). The duration and course of flashes have been measured by Cathode ray oscillograph and "Klydonograph." Latest results suggest that the time course of the potential-rise in conductors is very much influenced by the distance away of the flash, and that results on the surface of the earth do not give a representation true to time of the processes in the course of the flash.

ANFANGSPANNUNGEN FÜR MEHRFACH ELEKTRODEN IN LUFT (Initial sparking voltages for multiple-electrodes in air).—(*E.T.Z.*, 5 April, 1928, V.49, pp. 549-551.)

An investigation doing for multiple-electrodes what has already been done thoroughly for single electrodes, and thus giving information useful in connection with protective devices used on wireless receivers.

IONISATION OF THE UPPER ATMOSPHERE.—E. O. Hulbert. (*Journ. Washington Ac. Sci.*, April, 1928, V.18, p. 227.)

Author's abstract of a paper in which the form of the electron bank in the high atmosphere is calculated, using laws either known or based on reasonable assumptions. For a summer day (N. Temperate Zone) the max. density is about 3×10^5 electrons per c.c., at a height of about 200 km.: the corresponding values for a winter day are about 2×10^5 and 150 km., and for a summer or winter night about 8×10^4 and 100—150 km. There is an ion bank below the electron bank, whose max. density is probably less than 10^8 ions per c.c.

(Abstractor's note: No details as to the basis of the laws assumed are given in the Journal.)

PROPERTIES OF CIRCUITS.

Analyse einer Elektrischen Schaltung für das Kondensatormikrophon (Analysis of an electrical circuit for the Condenser-Microphone).—A. J. Jakowleff. (*Zeitschr. f. Hochf. Tech.*, March, 1928, V. 31, pp. 85–87.)

An analytical expression is derived for the current strength in a condenser-microphone circuit. The evaluation of the current shows that this circuit produces practically no distortion.

Zur Niederfrequenzverstärkung mit Drosselspulenkopplung (Low frequency amplification with choking-coil coupling).—H. Kafka. (*Zeitschr. f. Hochf. Tech.*, March, 1928, V. 31, pp. 87–90.)

A low-frequency amplifier due to E. E. Hiler, using two choking-coils and one condenser for the coupling of each step, is here dealt with. The relation of this coupling-method to the frequency is investigated. This dependence on frequency can be controlled within wide limits by variations of the inductance of the coils, so that practically uniform amplification can be obtained over a wide frequency-range. On the other hand it is possible to favour one chosen frequency-zone.

The adaptability of the method of coupling is strongly praised by the writer in comparison with transformer or resistance-couplings, which in their frequency-dependence show a rigidly un-uniform behaviour.

Applications Nouvelles des Lampes à Quatre Électrodes (New applications for four-electrode valves).—Decaux. (*Bulletin de la Soc. Franc. des Elec.*, February, 1928, V. 7, pp. 126–130.)

An article based on the work done during the past two years, in the Army radio-research laboratories, on double-grid valves. The Society's bronze medal was awarded to M. Decaux for his work on this subject. There are four subdivisions: (1) dealing with the use of the interior grid to allow a reduction of plate-voltage (with the advantage, *inter alia*, of small batteries: useful not only for portable or military receivers, but also for multi-stage H.F. amplifiers—since it facilitates the screening of each stage by allowing the inclusion of the battery), leading to experiments where the plate-voltage is supplied by the signals themselves. When a double-grid valve oscillates the power set free is very weak, so that parts of the apparatus can be brought nearer to each other without causing interference from the radiation from autodynes, etc. A new two-grid valve for low-frequency power-amplifiers has recently appeared which shows interesting properties. (2) Multiple-function valves: by using the interior grid as a second plate, double amplification (high and low frequency) is attained. A circuit is shown which gives particular stability. The principal use of the second grid is, perhaps, for the production of two different frequencies in the same valve, *e.g.*, for modulating. It also serves to provide, in an autodyne detector, a supplementary reaction free from loss of efficiency due to de-tuning. A four-valve h.f. amplifier for frames, very satisfactory for sensitivity and syntony, has been made on these lines for waves from 3,000 to 20,000 m. (3) Circuits for reaction by resistance or impedance coupling, made possible by the fact that the characteristic of the interior grid is in the reverse sense to that of the plate. Van der Pol and others have pointed out how these circuits can be used for the production of oscillations of "relaxation," *i.e.*, the periodic discharge of a condenser through a resistance, analogous to the results produced by neon tubes and multivibrators. The author has first employed them in connection with a cathode-ray oscillograph. Higher frequencies, with much lower voltages, are obtained than with neon tubes. The circuits have also been useful as a source of harmonics of known and constant frequency, useful for the precise measurement of wavelengths. By synchronising the circuit by a source of a sub-multiple frequency, a time-divider controlled by an astronomical pendulum has been made.

The circuit can be adjusted so as to act as an amplifier-relay of great sensitiveness (Siemens and Halske patent). By another modification, a notable anti-atmospheric effect by limitation is obtained.

(4) Future work outlined: in particular, a receiver with reaction for very short waves, in which tuning is practically independent of reaction; and a multi-stage receiver for waves of moderate length.

Determination of the Voltage-amplification-coeffient of H.F. Amplifiers with Resistances.—Witorsky and Konaschinisky (*Vestnik Elektrotech., Moscow*, February, 1928, pp. 77–80.)

The measuring is done by a thermionic-voltmeter connected not in the anode circuit (as is usual) but in the grid-circuit: greater accuracy is thus claimed.

Kettenleiter, (1) Drossel-und Kondensatorketten. (2) Siebketten. (Wave-filters, (1) Choking-coil-and condenser filters. (2) Wave-band filters).—H. Bock. (*Radio f. Alle*, April, 1928, pp. 157–162; May, 1928, pp. 196–200.)

and

Über das Verhalten Symmetrischer, Verlustfreier Kettenleiter zwischen ohmschen Widerständen (The behaviour of symmetrical, loss-free Wave-filters between ohmic Resistances).—R. Feldtkeller. (*Elek. Nachr. Tech.*, April, 1928, V. 5, pp. 145–159.)

Both these papers treat the subject mathematically.

TRANSMISSION.

PRODUCTION OF INTENSE EXTRA-SHORT ELECTROMAGNETIC WAVES BY "SPLIT-ANODE MAGNETRON."—K. Okabe. (*Journ. Inst. E.E. Japan*, March, 1928, pp. 284-290.)

Undamped waves from 20—30 cms. in wavelength are produced in a vacuum-tube containing a straight filament and a cylindrical anode split into two or more segments by narrow splits parallel to its axis; each segment having a separate lead-out which joins the others at a desired spot outside the tube. At this spot the anode-leads are brought near the cathode-lead, the distance being adjustable and having an effect of tuning. The anode segments and their separate leads form a resonant circuit. The tube is placed in a magnetic field which must be stronger than the "critical voltage" of the magnetron. An anode voltage of 320-950 volts is employed.

50 WATT AUS 220 VOLT! EIN EINFACHER UND LEISTUNGSFÄHIGER KURZWELLENSENDER (A simple and efficient short-wave transmitter). —W. Nestel. (*Radio f. Alle*, April, 1928, pp. 190-192.)

A description of a small 6-valve transmitter using the Meissner circuit.

TRANSMITTING AERIALS FOR BEAM STATIONS.—S. I. Turlyghin. (*Vestnik Elektrotech*, Moscow, Feb., 1928, pp. 69-77.)

A mathematical treatment of the subject.

RECEPTION.

UN SUPER-VALISE (A Super-" suit-case "-receiver). —G. Chaillon. (*Q.S.T. Francais*, April, 1928, No. 49, pp. 51-52.)

A description, with blue print, of a six-valve portable receiver using one double-grid valve.

NEW APPARATUS.—(*Electrician*, May 11, 1928, V.100, p. 539.)

A paragraph dealing with new receivers developed by the Marconi Company, including a number for naval and military use. By means of a new H.F. amplifier system it has been possible to produce a receiver operating over the large wave-range 300-22,000 metres.

A NEW METHOD OF PUSH-PULL (Advantages to be gained by Employing Tapped Loud-speaker Windings).—L. E. T. Branch. (*Wireless World*, 23 May, 1928, V.22, pp. 547-550.)

EINDVERSTERKERPROBLEMEN (Problems of the final stage of amplification).—B. D. H. Tellagen. (*Tijdschr. v.h.Ned. Rad.*, April 1928, V.3, pp. 141-160.)

The action of the loud-speaker valve is considered as regards quality, amplification, quantity and economy. Quality and amplification demand a valve whose internal resistance is high in comparison with the impedance of the loud-speaker. This can be reconciled with large quantity by putting a positive screen-grid between control-grid and plate. To prevent secondary emission a third grid between screen-grid and plate is necessary which can be connected directly to the filament.

CASCADE H.F. AMPLIFIERS (A Super-sensitive Receiver "by instalments.")—H. F. Smith. (*Wireless World*, 9 May, 1928, V.22, pp. 484-488.)

Description of a receiver in which each valve with its associated apparatus forms a separate screened unit.

AMPLIFICATION AND HIGH QUALITY (Permissible Gain per Stage for Good Reproduction).—N. W. McLachlan. (*Wireless World*, 2 May, 1928, pp. 463-466.)

EIN NETZANSCHLUSSEMPFÄNGER FÜR 220-VOLT GLEICHSTROM (A "mains-fed" receiver for 220 volts D.C. supply).—A. Leunig. (*Radio f. Alle*, May, 1928, pp. 209-213.)

A description of a 3-valve receiver completely supplied by the D.C. mains.

DIE ANWENDUNG DER RAHMENANTENNE (The use of frame-aerials).—E. Schwandt. (*Radio f Alle*, May, 1928, pp. 224-227.)

Right and wrong methods for the use of frame aerials with various types of receiver.

WERT UND WIRKSAMKEIT DES TONVEREDLERS (The value and efficiency of the "tone-improver".)—E. Schwandt, with reply by H. Kröncke. (*Radio f. Alle*, May, 1928, pp. 204-206.)

A discussion on the desirability of the use of a "tone-improver"—an external filter-circuit between receiver and loud-speaker. Dr. Kröncke's view is that such a device is useful only for poor receivers and poor loud-speakers.

WEITERES ÜBER DIE SCHIRMGITTERRÖHRE (More about the Screened-grid Valve).—H. Kröncke.

and

EIN EMPFÄNGER MIT SCHIRMGITTERRÖHRE (A receiver with screened-grid valve).—O. A. Klotz. (*Radio f. Alle*, May, 1928, pp. 213-215.)

Short articles on the subjects indicated. The first writer refers to the work of J. Harmon, recently published in the *Wireless World*, and mentions that with the Marconi Company's valve an amplification of 80 times can be obtained without oscillation. The valve specified in the second article is the Philips "Miniwatt."

DIE VERWENDUNG VON WECHSELSTROMRÖHREN (The use of alternating current valves).—R. Wigand. (*Radio f. Alle*, May, 1928, pp. 206-208).

The use of special short-filamented valves directly heated by A.C. is satisfactory for near reception, but when much use of reaction is made for distant reception, indirect heating of the audion-valve by an auxiliary filament is advisable.

EIN FÜNFRÖHREN - INTERFLEX - EMPFÄNGER MIT ABSTIMMBARER ABSCHIRMUNG (A 5-valve-interflex-receiver with adjustable screening). —H. Günther. (*Radio f. Alle*, April, 1928, pp. 170-175.)

EIN REISE-EMPFÄNGER MIT EINER VIERFACHRÖHRE (A portable receiver with one four-anode valve).—N. Werner. (*Radio f. Alle*, May, 1928, pp. 194-195.)

EIN EINFACHER KURZWELLEN-EMPFÄNGER MIT ZWEIFACHRÖHRE (A simple short-wave receiver with double-anode valve).—W. Nestel. (*Radio f. Alle*, May, 1928, pp. 222-223.)

These three articles deal with special receivers. The four-anode valve used in the second receiver is so connected as to be equivalent to an audion plus three stages of low-frequency amplification.

DER BETRIEB EINES HOCHLEISTUNGS-TROPADYN-EMPFÄNGERS (The working of a high-efficiency Tropadyne receiver).—E. Schwandt. (*Radio f. Alle*, April, 1928, pp. 149-157.)

An improved heterodyne receiver with filter and balanced-out first valve (differential neutrodon).

EUROPA-EMPFANG IM LAUTSPRECHER MIT 2 BIS 3 RÖHREN (Reception of European stations on loud-speaker with 2 to 3 valves).—C. Riedel. (*Radio f. Alle*, April, 1928, pp. 147-149.)

The writer considers that in the average broadcast receiver too many valves are employed, and bearing in mind that such a receiver only reaches as far as its first valve can reach, and that two stages of L.F. amplification is enough for ordinary purposes, he bases his 2-3-valve receiver on (*a*) freeing the signals from interference in the most efficient circuit possible before they reach the first valve, and (*b*) working this valve in the most efficient way.

L'AMPLIFICATION À HAUTE FRÉQUENCE PAR TRANSFORMATEUR À SECONDAIRE ACCORDÉ (High-frequency amplification by transformer with tuned secondary).—G. H. d'Ailly. (*Q.S.T. Francais*, May, 1928, pp. 30-33.)

The conditions for maximum efficiency are treated mathematically.

HARMONIQUES ET SUPER-RÉACTION.—L. La Porte. (*Q.S.T. Francais*, May, 1928, pp. 34-38.)

The use of the advantages of super-regeneration without prejudicing the reproduction of essential quality or "timbre."

VALVE CRYSTAL RECEIVER: A NON-RADIATING SUPER-SENSITIVE ONE-VALVE LOUD-SPEAKER SET.—P. W. Willans. (*Wireless World*, 23rd May, 1928, V.22, pp. 553-556, and 30th May, pp. 573-577.)

VALVES AND THERMIONICS.

DIE STROMVERTEILUNG IN DREIELEKTRODENRÖHREN UND IHRE BEDEUTUNG FÜR DIE MESSUNG DE VOLTASPANNUNGEN (Current-distribution in three-electrode Valves and its importance for the measurement of Contact-potentials).—H. Lange. (*Zeitschr. f. Hochf. Tech.*, April, 1928, V. 31, pp. 105-109.)

The first instalment of a series whose scope is indicated by a table of contents comprising about twenty headings. The present paper deals with six :—

A. Theory of Current Distribution.

B. Experimental checking and discussion of Sources of Error. (1) The electric and magnetic field of the heating-current; (2) Space charges; (3) Secondary radiation, true reflection and back-diffusion; (4) Initial velocity distribution; (5) Contact-potentials.

It is concluded that the discrepancies between the theory and the experimental results cannot be explained by these five sources of error. A further source is suggested, namely, the thickness of the grid, any variation of which has an extreme influence on the current-distribution. The grounds for this become obvious when one considers the electron-paths. These therefore are dealt with in the next article.

ÜBER DEN EINFLUSS HOHER OHMSCHER ANODENWIDERSTÄNDE AUF DEN GITTERWIDERSTAND VON VERSTÄRKERRÖHREN (The influence of high ohmic Anode-resistances on the Grid-resistance of Amplifier-valves).—E. Döring. (*Zeitschr. f. Hochf. Tech.*, April, 1928, V. 31, pp. 116-120.)

A description of experimental work which resulted in agreement with Barkhausen's estimate. The high ohmic resistances work as if the vacuum of the valve were improved. For certain special purposes, where very high grid-resistance is desired, the use of valves with not very good vacuum is indicated, together with high anode resistances.

ELECTRON EMISSION IN INTENSE ELECTRIC FIELDS. —R. H. Fowler and L. Nordheim. (*Proc. Royal Society*, May, 1928, No. A.781, pp. 173-181.)

Experimental data, on the phenomenon of the extraction of electrons from cold metals by intense electric fields, have been much improved recently by Millikan and his associates Eyring and Lauritsen. They seem to have established quite definitely the laws of dependence of the emission on the field strength F, showing that a plot of log I, where I is the current, against $1/F$ yields a good straight line whenever the experimental conditions are sufficiently stable. At ordinary temperatures these currents are completely independent of the temperature, but as the higher temperatures, at which ordinary thermionic emission begins, are approached, the strong field emission does become sensitive to temperature, and finally blends into the thermionic. On the strength of these facts they suggest that perhaps there may exist a general formula for the current

$$I = A\,(T + cF)^2 e^{-b/(T + cF)},$$

valid over wide ranges of T and F. The writers of the present paper, however, extend the results of Nordheim to include the effect of an external field, using the same methods and the same underlying picture of the metal (Sommerfeld's). They fail to find any theoretical justification for the above formula, though some justification may exist (it is true, of course, for large T and small F and for small T and large F; but for intermediate strengths it does not appear to have been tested quantitatively and awaits experimental and theoretical investigation). But they show that Sommerfeld's picture of a metal yields the formula both for strong fields and for thermionic emission, and that a single set of free or conduction electrons distributed according to the Fermi-Dirac statistics suffices for both purposes. They therefore strongly deprecate another deduction of Millikan and Lauritsen, namely, that a distinction should be drawn between the electrons which can function as thermions and the ordinary conduction electrons which yield the emission at great field strengths and are absolutely independent of the temperature.

On the Cause of the Loss of Thermionic Activity of Thoriated Tungsten Filaments under certain Voltage Conditions.—A. C. Davies and R. N. Moss. (*Phil. Mag.*, May, 1928, V. 5, No. 31, pp. 989-1010.)

This work was carried out as part of the programme of the Radio Research Board. The writers sum up their results by stating that there does not appear to be any necessity for attributing any appreciable part of the observed de-activation to any factor other than bombardment of the filament by positive ions, which originate in their turn from the electron bombardment of the grid and plate.

Space-charge Effects.—E. W. B. Gill. (*Phil. Mag.*, May, 1928, V. 5, No. 31, pp. 859-865)

The writer refers to his former experiments with a gas-free three-electrode valve, in which the current from the filament to the plate was investigated, the plate being kept at a few volts, and the grid at from 20 to 30 volts, positive to the filament. It was found that the space-charge between grid and plate had a considerable effect on the electric field in that region, and when the current was sufficiently increased discontinuous changes took place in the field. The theory which was given has recently been extended by Tonks.

The present investigation comprises a further extension of the experiments to the case in which the plate is a little negative to the filament.

Results were obtained which could only result from disturbances of the field, proving that the emission from a filament, though very steady, is not steady enough to prevent such changes.

Über die Gleichzeitige Erregung Zweier Schwingungen in einer Dreielektrodenröhre (The Simultaneous Excitation of Two Oscillations in One Three-electrode Valve).—Hans Mögel. (*Zeitschr. f. Hochf. Tech.*, Feb., 1928, V. 31, pp. 33-39; March, 1928, V. 31, pp. 72-84 and plates.)

The normal overtones existing in a valve simultaneously with the fundamental oscillation, and due substantially to the departure of the anode-current from the sinusoidal form, are neglected in this paper, which deals with the simultaneous existence of two oscillations whose frequencies are entirely independent of each other.

In the first part is considered an oscillation of frequency f_2 which can be formed in the presence of a back-coupled oscillation f_1, but is itself not produced by back-coupling.

In the second part the author deals with the simultaneous production of two back-coupled stable oscillations, and discusses some practical applications of his results in connection both with transmission and reception. He concludes that the deliberate excitation of two simultaneous oscillations in a single valve is not likely to have much practical value even in multiple-tone telegraphy or for test-room purposes; two valves being more practicable than one valve plus the filter circuits which would be necessary.

He then considers the use of the second oscillation as a modulator of the first, and refers to the self-excited "tone-sender" of Mauz and Zenneck; deals with the case of stray oscillations, such as endanger the life of large valves; Armstrong's "super-regenerative" circuit; and the reflex-connections of tropadyne receivers.

The papers are profusely illustrated.

A propos de la Recherche de la Démodulation Parfaite (The search after perfect demodulation).—G. E. Petit. (*Rev. Gén. de l'Electricité*, 7th April, 1928, V. 23, pp. 607-608.)

The author briefly recalls the principle of demodulation and the ideal conditions for the functioning of a detector for electric waves. In practice, these conditions are not as a rule realised, from the fact that the acute angle of the characteristic is replaced by a parabolic arc more or less bent. The author shows that this bend is entirely due to the fall of heating voltage along the filament constituting the cathode. It disappears or, at any rate, is much reduced, by the use of equipotential cathodes. Great progress has recently been made on these lines by decreasing the heating voltage from 4 volts to 0.5 volt and by the use of oxide-coated filaments in parallel.

Détermination de la Condition d'Entretien et de la Période d'Oscillation d'un Oscillateur à Triode (Determination of the condition for the maintenance of oscillation and of the period of the oscillation, in a three-electrode valve oscillator). — L. Abélès. (*Rev. Gén. de l'E.*, 21st April, 1928, V. 23, pp. 696-701.)

The work of Blondel and Lavandry and of Gutton is mentioned, the method of the latter being considered too complex in the case of valves characterised by a differential equation of more than the second order. The author's method is more simple in its application to such problems. It shows that the resolution of the equations which determine the conditions for the maintenance of oscillations can be brought down to the study of a quadripole constituted by the impedances of the grid and plate circuits and by the couplings between these circuits. The method is therefore elementary and the resolutions are done by means of determinants. The author applies it to nine types of oscillators corresponding to more or less complex systems of linking between the electrodes.

Über die Kompensation der Schädlichen Kapazitäten und Ihrer Rückwirkungen bei Elektronenröhren (The compensation for undesired capacities and their effects in valves). — V. Ardenne and W. Stoff. (*Zeitschr. f. Hochf. Tech.*, April, 1928, V. 31, pp. 122-128.)

The first part of a long paper which brings together under mathematical treatment the various methods of other workers. This first part comprises —A. Introduction, showing the bad influence of these capacity effects in cascade amplifiers; B. The nature of the effects; C. Their compensation: (1) valve-circuits with sharply tuned couplings: (*a*) abolition of tendency to oscillate, by complete neutralisation (circuits of Loftin and Young White, Hazeltine, Barber and others); (*b*) neutralisation arrangements with regeneration (Leithäuser, Scott-Taggart, Reinartz and others); and (*c*) combination methods.

Sur un Nouveau Mode d'Entretien d'Oscillations dans les Lampes Triodes (A new manner of producing oscillations in three-electrode valves).—E. Pierret. (*Comptes Rendus*, 7th May, 1928, V. 186, pp. 1284-1286.)

The author obtains waves of 14 to 18 cm. length, very stable, and of an intensity at least equal to that obtained by Barkhausen at 45 to 50 cm. He states that the latter worker only obtained stable waves down to about 30 cm., and that the two methods are very different; *e.g.*, the author's method, using two valves, is such that the electrons from the filament never reach the plate, whereas the Barkhausen oscillations are only produced if the electrons reach the plate. The author suggests that the oscillations obtained irregularly by Scheibe were of the same nature as (though longer than) the ones now obtained in a stable form.

DIRECTIONAL WIRELESS.

Directional Wireless and Marine Navigation: the Rotating-Loop Beacon.—R. L. Smith-Rose. (*Nature*, 12th May, 1928, V. 121, p. 745.)

The rotating beacon system of directional wireless transmission has been developed to a high degree in Great Britain by the Royal Air Force, as providing a method of navigating aircraft without necessity of carrying additional and elaborate apparatus in the machine itself. In a previous latter to *Nature* the writer mentioned that the application of the method to marine navigation was under investigation. In his present letter he states that the results of these experiments show that the method will prove of great importance in the future application of directional wireless to marine working, gives a description of the method, and summarises the main results arrived at.

Among these might be mentioned that bearings by the beacon system at distances over 60 miles oversea are subject to night effects similar to those experienced in wireless direction-finding. He sums up thus: "From a scientific point of view, it thus appears that while there is little to choose in direction-finding between the rotating-loop transmitter and the rotating-loop receiver, the former may have a slight advantage for navigation purposes. It must remain for the mariner himself to become familiar with the operation and performance of each system and to determine the sphere of their application as scientific aids to modern navigation."

Construction rapide, sur la carte, des lignes de relèvements constants pour utiliser les relèvements radiogoniométriques pris du bord (Quick construction on the chart of "lines of constant bearing," to utilise the D.F. bearings taken on board ship).—D. Gernez. (*Comptes Rendus*, 7th May, 1928, V. 186, pp. 127-1280.)

Direction-finding bearings on a land-station taken on board ship cannot be transferred directly to the chart, being great circle arcs. By drawing, however, on the chart the "lines of constant bearing" (*i.e.*, the loci of the positions at which the bearing of the station is n°) the D.F. bearings can be used directly. The method of plotting these "lines of constant bearing" is described.

MEASUREMENTS AND STANDARDS.

Verfahren zur Ermittlung der wirksamen Höhe von Antennen und des Empfangs wertes einer Anlage unter Mitbenutzung des Biot-Savartschen Feldes in unmittelbarer Antennennähe (A method of ascertaining the effective height of Aerials and the receptive value of an installation by the aid of the Biot-Savart Field in the immediate neighbourhood of the aerial).—Max Dieckmann. (*Zeitschr. f. Hochf. Tech.*, March, 1928, V. 31, pp. 65-72.)

This method, particularly for receiving aerials, is based on the comparison between the field strength produced at the receiving points by the distant transmitter, and the Biot-Savart Field caused by the current in the receiving aerial.

The comparison is accomplished by means of a frame receiver, which is oriented, first, so that it receives only from the distant sender; and, secondly, so that it is excited only by the aerial under examination.

International Comparison of Radio-frequency Standards: Testing and adjusting Piezo Oscillators.—(*Bureau of Standards, Technical News Bulletin*, February, 1928, No. 130, pp. 13-15.)

The increase in power of many United States and foreign radio stations, making them international in their effects, raised the question as to whether or not the national standards of radio-frequency of the various governments are in agreement. Since 1924 the bureau has made several comparisons of frequency standards with the national laboratories of other countries. These showed satisfactory agreement to the accuracy then required. During the past year, however, it became important to know such agreement much more accurately, and the development of the temperature-controlled Piezo oscillator offered a means of doing this. As a result, the bureau found the average departures from the mean to be 3 parts in 100,000, the countries being the U.S.A., England, France, Italy, and Germany. The bureau considers this agreement to be surprisingly good, representing, as it does, an average difference of only 0.03 kilocycle at 1,000 kilocycles (300 metres), which is much smaller, for instance, than the variation 0.5 kilocycle allowed to broadcasting stations in the U.S.A. The second article deals with the use of Piezo oscillators, particularly by broadcast stations in America, to enable them to comply with the regulations as to a 0.5 kilocycle variation. It mentions the publication by the bureau of specifications for a portable Piezo oscillator for this purpose, and the "rush" which the bureau has experienced for its services in testing and adjusting oscillators destined for this use.

Evaluation of the Capacity of Flat Condensers in the case of Unparallel Plates.—Florensky and Popoff. (*Vestnik Elecktrotech, Moscow,* Feb. 1928, pp. 41-45.)

The authors derive formulæ for the above calculations for plates of various shapes.

Leistungs- und Strahlungs-Messungen an Flugzeug- und Bodenstationen (Power- and radiation-measurements in aeroplane- and land-stations).—Eisner, Fassbender and Kurlbaum. (*Zeitschr. f. Hochf. Tech.*, April, 1928, V. 31, pp. 109-116.)

The first part of a long paper on work undertaken to bring clarity on the power and radiation of aeroplane aerials. The work showed that existing publications gave unsatisfactory information on the same questions as regards land-stations, so that it had to be extended to these. The present instalment deals with I. Power-measurements on aerials. (1) Theoretical basis for power measurements by the means of added resistances and use of high frequency; (2) Description of the methods employed in the present experiments; (3) Experimental results in power-measurement on Aeroplane- and Land-stations.

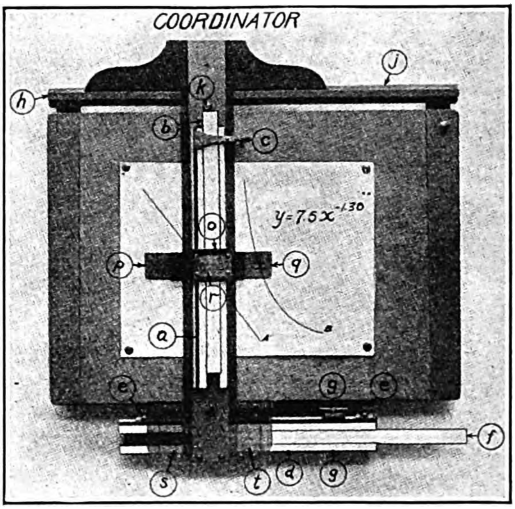
Eine Neue Methode zur Experimentellen Aufnahme der Richtkennlinie einer Antenne (A new method for the experimental plotting of the directional-characteristic-curve of an aerial).—F. A. Fischer. (*Zeitschr. f. Hochf. Tech.*, April, 1928, V. 31, pp. 121-122.)

Previous methods involved either touring round the aerial with a transmitter and measuring the received energy, or exciting the aerial and exploring round it with a receiver which measured the radiated energy. Both methods involved the intensity of the radiated energy, and both therefore were liable to errors due to absorption in the surrounding (and not uniform) earth. The present method is free from this defect as it does not involve the intensity. A tour is made round the aerial with a transmitter, and near the aerial a directional-receiver is employed to measure the apparent deflections of the waves from the transmitter, due to the re-radiated field from the aerial.

SUBSIDIARY APPARATUS AND MATERIALS.

An Improved Co-ordinator.—R. A. Castleman, Jnr. (*Journ. Opt. Soc. America*, April, 1928, V. 16, pp. 287-292.)

A plotting and computing device, assembled from a T-square, a drawing-board, two slide-rules and certain machined accessories. It is adapted for use as a log, semi-log and uniform co-ordinator, and among other things is particularly adapted to the *complete* treatment of equations of the form



$$y = x \cdot . u^n, \; y = b \,.\, 10^{mx},$$
$$y = b_1 e^{m_1 x}, \; y = c \,.\, \sin^n x, \text{ etc., etc.}$$

A New Type of Selenium Cell.—R. E. Martin. (*Journ. Opt. Soc. America*, April, 1928, V. 16, pp. 279-281.)

A cell of high sensitivity in which the conducting part is cylindrical, this shape offering certain advantages, *e.g.*, the current density at any point is easy to calculate for D.C. and A.C.; the electrodes can be changed easily; the electrodes can be kept in the dark while the central parts of the selenium are exposed. Resistance was of the order of 5×10^8 ohms in the dark, and light sensitivity was from 40 per cent. to 75 per cent. The process of annealing is described.

AN OPTICAL METHOD OF MEASURING SMALL VIBRATIONS.—H. A. Thomas and G. W. Warren. (*Phil. Mag.*, May, 1928, V. 5, No. 32, pp. 1125-1130.)

An interferometer method of measuring small mechanical vibrations, such as those encountered in telephone diaphragms and structures, is described.

DAS OSZILLOSKOP (The Oscilloscope).—Bedell and Reich. (*E.T.Z.*, 3rd May, 1928, V. 49, p. 689.)

Disadvantages of the Cathode-ray Oscillograph include: (1) the non-linearity of the time-axis, and (2) the impossibility of superimposing several curves, as can be done with multi-looped oscillographs. The methods here described avoid both of these disadvantages, the first by the use of a rotating commutator, and the second by an application of the fact that a condenser uniformly charged through a resistance shows an increasing voltage linear with the time.

REDRESSEUR "OXYMÉTAL" POUR COURANT ALTERNATIF, À RONDELLES DE CUIVRE OXYDÉ ("Oxymetal" Rectifier, for alternating current, comprising washers of oxidised copper).—C. Chouquet. (*Génie Civil*, 14th April, 1928, V. 92, pp. 364-365.)

A description of a rectifier involving neither liquids nor moving parts, and suitable either for charging accumulators or—in certain cases—for dispensing with the use of these by supplying current direct to apparatus requiring continuous current. The rectifier is composed of a number of copper washers, each oxidised on one face, separated by washers of soft metal, such as lead, and clamped firmly together. Cooling fins of copper are provided. The rectifying action is due to the considerable difference between the resistance opposed to the passage of the current in the direction copper-oxide and that in the direction oxide-copper. After the passage of the current no change, chemical or physical, can be noticed.

Explanations of the phenomenon are discussed.

SUR L'ADAPTATION DES OSCILLOGRAPHES BIFILAIRES À L'ÉTUDE DES LAMPES TRIODES (The adaptation of bifilar Oscillographs to the study of three-electrode valves).—André Blondel. (*Comptes Rendus*, 16th April, 1928, V. 186, pp. 1034-1036.)

The bifilar oscillograph of 1893 was improved to meet the demands of greater sensitiveness and higher frequency by various changes in design, but even so it was not satisfactory for the study of three-electrode valves. To this fact the writer attributes the increasing use of what he calls "telephonic oscillographs," *i.e.*, instruments based on the construction of certain refined forms of telephone such as those of Brown or Baldwin.

He considers the use of these as a retrograde step, liable to introduce errors caused by their high self-induction and also by their methods of damping; and recommends a return to the bifilar oscillograph, which can be rendered satisfactory for valve-work by the use of a suitable transformer (somewhat like those used in the low-frequency stages of a valve-amplifier) transforming down to a bifilar loop of low resistance (.5 to 1 ohm).

A NEW QUICK-TUNING VIBRATION GALVANOMETER WITH CALIBRATED TUNING.—D. C. Gall. (*Journ. of Scientific Instruments*, April, 1928, V. 5, pp. 134-135.)

An illustrated description of a modified form of a standard moving-coil vibration galvanometer intended for use in the duplexing of submarine cables, where it is desirable to tune immediately to a required frequency without any process of tuning by trial. The tuning is carried out by the simultaneous adjustment of the position of the bridge pieces, between which the suspended coil vibrates, and the tension of the suspension strip itself; a large milled disc being turned until the desired frequency is opposite the index. Three different suspension pieces cover the total range of 3 to 300 cycles.

L'ALIMENTATION DES POSTES RÉCEPTEURS (The supply of electricity to receiving sets).—J. Granier. (*Q.S.T. Français*, April, 1928, No. 49, pp. 46-50.)

A short practical article dealing with the charging of accumulators from D.C. mains; from A.C. mains by means of various forms of rectifiers—vibrating, rotating, electrolytic and thermionic; the abolition of accumulators and high tension batteries by the use of mains both for filament and plate ("when extreme sensitiveness is not required, *i.e.*, for local or powerful stations"); precautions and refinements necessary.

SUR L'EFFET DE SOUPAPE PRÉSENTÉ PAR LES ÉLECTRODES EN SILICIUM (Rectifying effect of silicon electrodes). — M. Aubert. (*Recherches et Inventions*, March, 1928, quoted in *Rev. Gen. de l'Elec.*, 12th May, 1928, V. 23, p. 824.)

Deals with a rectifier using an electrode of silicon (or derivative) associated with one of iron, platinum, carbon or lead, in an acid or basic electrolyte. Practical advantages over other electrolytic rectifiers are said to be (1) no forming-current needed; (2) the electrolyte can rise nearly to boiling point without seriously upsetting the working; (3) the silicon electrode is not attacked either in working or in rest; (4) rectification is excellent and the efficiency can, under certain conditions, reach the theoretical maximum.

PROTECTION OF . . . . . LINES AGAINST OVER-VOLTAGE.—E. Beck. (*Journ. A.I.E.E.*, May, 1928, V. 47, pp. 332-336.)

At the end of this article is described a special protection to relieve lightning voltages. The breakdown voltage is 350 to 500 v., and the protector will handle many times discharges of 50 ampères of two seconds duration. It will take care of heavier discharges up to hundreds of ampères, but at a sacrifice of length of life. The gap is enclosed in argon at reduced pressure.

Safeguarding Batteries and Valves : How to Use Protective Fuses. (*Wireless World*, 23rd May, 1928, V. 22, p. 551.)

Bridge for Measuring Small Time Intervals.—J. Herman. (*Bell Tech. Journal*, April, 1928, V. 7, pp. 343-349.)

In the form described, this method is applied to measuring the time elapsing between the opening or closing of one set of contacts and the opening or closing of another set. Intervals from about 1/10,000th sec. to several seconds can be measured with fair accuracy, and can be read off directly. The method depends on the charging of a condenser through a resistance.

Ein Empfindliches Röhrenvoltmeter für Hochfrequenz (A sensitive Valve-voltmeter for High Frequency).—M. von Ardenne. (*E.T.Z.*, 12th April, 1928, V. 49, pp. 565-567.)

This instrument has a capacity of only 7.4 cms. and can be used to measure peak-voltages down to 0.03 v. or with anode-current compensation down to 0.003 v.

Ein Wechselstrom-Netzanschlussgerät zur Gleichzeitigen Entnahme der Heiz und der Anodenspannung (An arrangement for obtaining heating- and Anode-voltage simultaneously from the public A.C. supply).—J. Schad. (*Radio f. Alle*, April, 1928, pp. 162-165.)

A description, with diagrams, of a method using a glow-discharge rectifier valve (Raytheon valve), a two-anode valve working at 250 v. and giving 350 milliampères.

Die Trockenplatten-Gleichrichter (The dry-plate rectifiers).—H. Fröhlich. (*Radio f. Alle*, April, 1928, pp. 165-170.)

A survey of the various dry-plate rectifiers recently developed, *e.g.*, the copper-oxide, vanadium-pentoxide-wolfram, and other combinations.

Du Fonctionnement et de l'entretien des Accumulateurs (The Working and Maintenance of Accumulators).—M. Devauchelle. (*Q.S.T. Français*, May, 1928, pp. 20-29.)

A practical article, the last part of which deals with the various forms of rectifier for charging from A.C. mains.

L'Accumulateur Léger (The Light-weight Accumulator).—J. Granier. (*Q.S.T. Français*, May, 1928, pp. 12-14.)

Discussing the light-weight " Almeida " accumulator using a carbon positive electrode, a zinc negative, and an electrolyte of chloride or bromide of zinc. The writer considers that this accumulator cannot at present compete with the lead type, but that it is capable of improvement.

L'Alimentation des Postes de T.S.F. (The supply of electricity to Radio-stations).—P. Olinet. (*Q.S.T. Français*, April, 1928, No. 49, pp. 37-45.)

A previous article (*Q.S.T. Franc.*, No. 48) dealt with rectifiers : the present deals with the question of the filtering necessary to make the rectified current suitable from the point of view of quality. The question is studied in considerable detail by means of curves and simple mathematics.

Constant Speed Mechanism for an Accuracy of 1 in 10,000. (*See* Miscellaneous, " Picture Reception.")

STATIONS, DESIGN AND OPERATION.

La Radiotéléphonie par Ondes Courtes Projetées : les Premières Communications entre Paris et Alger (Radiotelephony by short-wave beam : the first communications between Paris and Algiers).—R. Nöel. (*Génie Civil*, 21st April, 1928, V. 92, pp. 373-379.)

The work of the Administration of Posts and Telegraphs, in collaboration with the French radio electric industry, in linking-up the French and North-African telephone systems, has shown that a public radio-telephone system no longer presents technical difficulties. Last March, one-way communication was established from Paris to Algiers, and only the absence of a transmitting plant at Algiers prevented normal two-way communication.

The writer first mentions the esential differences between radio-broadcast (already arrived at a remarkable degree of perfection) and radio-telephony proper, of which only one example in regular service exists (England—United States, with extensions to Cuba and Canada, France and Belgium). Unlike radio-broadcast, radio-telephony should provide communication similar to that of the ordinary telephone, independent of hours or seasons, across seas and frontiers, with enough secrecy for commercial use, by the employment of the same instruments and with the same reliability as in the case of a good telephone system. It has, therefore, two problems : the satisfactory linking-up of the telephone subscribers to the transmitting and receiving stations and the establishment of a permanent and reliable radio-electric liaison.

After dealing briefly with the first problem, and mentioning in passing one of the various methods of obtaining the requisite secrecy (transposing the frequency of modulation at its entry to the modulating organs of the transmitter), the writer criticises the England-America system of long-wave transmission on the grounds of interference by atmospherics and of high cost, and points to short-wave beam telephony as the only real solution, economically providing, as it does, a reserve strength of signal for passing out to the landlines, even under the worst conditions of propagation.

After detailing various advantages of short waves, he outlines the method (due to Franklin) adopted by the Marconi Company for realising beam transmission. This also he criticises as only partially effective, complicated and costly, and claims considerable advantages for the aerial-system Chireix-Mesny (used in the Paris-Algiers tests) adopted by the Société française Radio-électrique. He deals at some length with the theory and practice of this aerial system, aided by pictures and diagrams, including one diagram of the energy radiated from a single-bay C.M. aerial. He passes on to the consideration of the transmitting plant (where the wave-frequency is stabilised by piezo-electric means) and of the receiving plant, where the stability of reception is assured by the total absence of reaction, by a great reserve of amplification, and by an automatic "fading-compensator."

Der Neue Deutschland-Sender bei Königswusterhausen (The new "Germany transmitter at . . . .).—W. Kummerer. (*E.T.Z.*, 17th May, 1928, pp. 741–745.)

A description, with illustrations, connection diagrams, modulation curve, etc., of the transmitter put in commission at the end of 1927. Power in aerial is 30 kW. at rest (corresponding to 75 kW. rating for broadcasting stations), six times as great as the former set. For telegraphy the aerial power is 120 kW.

Transatlantic Telephony—The Technical Problem.—O. B. Blackwell. (*Bell Tech. Journ.*, April, 1928, V. 7, pp. 168–186.)

The paper read as a preface to the Joint Meeting (by wireless telephone) of the English and American I.E.E. It describes in a non-technical way the engineering problems involved in developing the transatlantic radio trunk by means of which the American telephone system of some 18,060,000 telephones can communicate with the English system of about 1,500,000 telephones, and also with the systems of other European countries. Among the many interesting points may be mentioned the following. Two plots, on a logarithmic scale, one of the radio spectrum and the other of general frequencies ranging from Donati's comet (period 2,000 years) to cosmic rays (Millikan) of frequency about 10^{22}; on the radio spectrum, one frequency near the lower end and one near the upper end appear to be most suitable for trans-oceanic transmission (about 60,000 and 10,000,000 to 20,000,000 frequencies). Photographs of transmitting and receiving aerials for the long-wave transmission, and also for the short-wave system held in reserve (at present only eastwards) as an emergency routing and used in the summer of 1927 during the severe static season. Refinements in transmission methods for greater economy in power: single side-band carrier-suppression method, double frequency transformation. Long-wave curve and corresponding short-wave curve of received field strength showing variations over 24 hours; the advantage in employing a number of separate wave-lengths for choice at any time. Great circle routes for long and short-wave circuits; reception from a northerly direction, static coming chiefly from the opposite direction. Location and directional characteristics of the receiving aerials equivalent to a transmitted power increase of 5,000 times. Linking to the land-systems; dangers of echo and building-up of oscillation; voice-actuated relays. For American-Europe communication, long-waves cannot (so far as can be seen) be replaced by short. Privacy: new method probably in experimental use shortly.

The Design and Distribution of Wireless Broadcasting Stations for a National Service.—P. P. Eckersley. (*Journal of I.E.E.*, May, 1928, V. 66, pp. 501–528.)

This gives the paper read before the Wireless Section on 1st February, 1928, and the subsequent discussion. In his summary, the author says that his paper attempts to be comprehensive and therefore cannot in a manageable length fail to be more qualitative than quantitative. The comprehensiveness is indeed best indicated by giving the sub-headings and an occasional extension, thus: Part I. (1) Historical (in Britain); (2) Service Area (division into four areas, from "wipe-out area" where field strength is > 30 millivolts per metre, to "C" area in which it is > 2.5; nature of service in each area); prediction of Service Area, depending on wave-lengths, type of ground, design of transmitting aerial; use of medium waves (800–600 k cycles); advantages and disadvantages of long waves (200 k cycles). This portion includes curves showing alteration of field strengths with distance, for various powers. (3) Limitation of wave-lengths; required separation of fundamental frequencies; theoretical considerations; the "Plan de Genève." (4) Provision of Alternative Programmes. (5) Linking together of Stations (*a*) in same country, (*b*) from country to country; short waves most likely to provide the required link? fading; equalising intensity of received signals; spaced aerials? reflectors? (6) Single wave-length working—same programme on same wave-length from two or many stations; synchronisation by master-drive; not yet satisfactory. (7) Distribution of Stations for a National Scheme. Part II. (1) Design of Transmitters; types; choke-modulation, high-power and low-power modulation systems; comparison between these two systems; Valve point discharge; anode power supply from economic view point. (2) Conclusion. The illustrations include circuit diagram of 5 GB, illustrating the general principle of low-power modulation with subsequent amplification at high frequencies.

Wireless Masts and Screening. (1. The Aerial Support and its Effect on Signal Strength; and 2. Some Considerations in Erecting a Broadcast Receiving Aerial).—R. L. Smith-Rose. (*Wireless World*, 2nd May and 9th May, 1928, V. 22, pp. 460–462 and 497–498.)

Die Störbefreiung in der Drahtlosen Telegraphie nach dem Verfahren "Baudot-Verdan" (The prevention of interference in Wireless Telegraphy by the "Baudot-Verdan" system).—(*E.T.Z.*, 19th April, 1928, V. 49, pp. 623–625.)

A description of the system already used in France with success, based on the repetition of each letter of each word either once or twice, the repetitions not following directly on the first sending of the letter but being separated by (*e.g.*) four other letters. It has been calculated that for a given number of short interferences, which would on the ordinary Baudot system spoil every fourth word, the Verdan modification with one repetition would lose one word in 272 or with double repetition only one word in 5,820.

GENERAL PHYSICAL ARTICLES.

A Suggested Arrangement for the Determination of the Velocity of Light.—N. Deisch. (*Journ. Opt. Soc. America*, April, 1928, V., 16, pp. 272-275.)

A method using, as modulator, electro-optic cells supplied with H.F. oscillating potential. The pulsating beam can have its frequency rigorously controlled by a calibrated piezo-electric resonator. Thus the limitations inherent in the use of mechanical devices such as a rotating multi-sectored disc or multi-faced mirror are avoided, and, moreover, very much higher frequencies can be used than with mechanical modulation methods.

The Shadowgraph Method as Applied to a Study of the Electric Spark.—H. A. Zinszer. (*Phil. Mag.*, May,1 928, V. 5, No. 32, pp. 1098-1103.)

The apparatus and methods described are essentially the same as that devised by Foley and Souder for photographing sound-waves.

Un Nouveau Phénomène d'Optique (A new phenomenon in Optics).—J. Cabannes. *Comptes Rendus*, 30th April, 1928, V. 186, pp. 1201-1202.)

Raman has just discovered that the spectrum of the light diffused by a perfectly pure liquid contains not only the incident radiations, but also new radiations whose place in the spectrum depends jointly on the incident light and on the chemical constitution of the liquid. These new radiations are much less intense than those diffused without change of wavelength, but they are distinguished from ordinary fluorescence by their strong polarisation. Raman, to explain this remarkable phenomenon, considers it an effect analogous to the Compton effect. The writer, however, sees in it the phenomenon of "optical beats" (entirely analogous to the ordinary acoustic beats) which he predicted in 1924, but looked for in vain in gases. The derivation of these beats is shown mathematically.

Polarisation Rotatoire—Calcul du pouvoir rotatoire du quartz (Rotatory Polarisation—Calculation of the rotating power of quartz).—de Mallemann. (*Comptes Rendus*, 16th April, 1928, V. 186, pp. 1046-1048.)

A previous paper outlined a theory on the electrical properties of quartz considered as an effect of orientation of the polar anisotropic molecules, and this is a further development based on the experimental results of Ny Tsé Zé.

Les idées nouvelles sur la structure de l'éther (The new ideas on the structure of the ether).—G. Giorgi. (*Rev. Gen. de l'Elec.*, 14th April, 1928, V. 23, pp. 643-653.)

Professor Giorgi shows the evolution of ideas from Newton, Huygens and Descartes through the epoch of the first discussions on the drift of the ether and the theories of Cauchy, Stokes and Fresnel. He reviews the hypotheses of Maxwell and Lorenz, and then deals with the origins of the Relativity theories, formulating the conceptions of the ether led to by these theories. He shows how the Quanta theory can be reconciled with the conception of the ether and how this last view imposes itself on the new undulatory physics of de Broglie and Schrödinger. He ends with an exposition of his personal views.

A bibliography of 49 references is appended, ranging from Newton to Einstein, Millikan, de Broglie and Schrödinger.

Au sujet de la relativité et de Lorentz (Concerning Relativity and Lorentz).—Général Cartier. *Q.S.T. Français*, April, 1928, No. 49, pp. 2-4.)

An instalment of a series of articles by this writer under the heading "Radiotelephony and the phenomena of propagation." In the present article he defends himself against a number of correspondents who attack his anti-Einstein views. One correspondent, assuming that the author could only have read bad translations of Einstein's work, recommended him to read one translated into French by Mlle. Rouvière, entitled "The Theory of Relativity restrained and generalised." The author did as he was told, and strongly commends the book to those who wish to know, without formulæ, the essential ideas of Einstein. He then proceeds to contest point after point in it.

The High-frequency Electric Discharge at Low Pressures.—J. Taylor and W. Taylor. (*Proc. Cambridge Phil. Soc.*, April, 1928, V. 24, pp. 259-267.)

A paper dealing with further studies of electrical discharges through gases under the influence of H.F. oscillations of the order of 10^7 cycles per sec. Even at the highest degree of exhaustion, faintly luminous discharges could be obtained. The absence of luminosity and the difficulty of maintaining uni-directional or low-frequency discharges at very low pressures may arise from (1) the infrequency of collisions between gas atoms or molecules and electrons, preventing cumulative ionisation by collision; (2) the loss of electrical charges to the metal electrodes, and (3) the separation of the positives and negatives under the influence of the field.

In the high-frequency discharge, those inherent difficulties may be overcome. Experiments were made regarding the condensation of the luminosity along the tube and round corners: the electrical effects due to the wall were studied, also the effect of adding an extra quota of electrons, the effects of magnetic fields, and spectra observations.

Remarques sur la Théorie de la Lumière, Énergie, Cohérence et Franges Supplementaires (Remarks on the theory of Light, Energy, coherence and supplementary fringes).—F. Wolfers. (*Comptes Rendus*, 30th April, 1928, V.186, pp. 1198-1201.)

The writer concludes that in the phenomenon of supplementary fringes an effect is met with, for the first time, which it is impossible to explain by an undulatory theory only or by a "quanta theory" only. A more general theory, at present non-existing, is necessary.

Untersuchung und Theorie der Pyroelektrizität (Investigation and theory of Pyroelectricity).—Meissner and Bechmann. (*Zeitschr. f. Tech. Phys.*, May, 1928, pp. 175-186.)

Quantitative experiments on the pyroelectric behaviour of tourmaline and of quartz are described, and an interpretation of pyroelectricity is deduced from the structure of the latter. According to these views, it is unnecessary to assume a distinction between true and false pyroelectricity—*i.e.*, to assume that heat first produces special mechanical tensions and deformations, which by way of piezoelectrical action produces pyroelectricity. This view is supported by experiments on piezoelectric crystals in powder-form, which show pyroelectric effects as great as or greater than those shown by plates of the same material. The paper ends with full calculations of the pyroelectric constants, which agree satisfactorily with experimental results.

Quelques Difficultés Expérimentales de la Théorie Électromagnétique du Rayonnement de la Lumière (Some experimental difficulties in connection with the electromagnetic theory of Light).—A. H. Compton. (*Journ. Franklin Inst.*, February, 1928, pp. 155-178.)

The writer concludes that there is no doubt that radiations are constituted of separate quanta of energy—*i.e.*, of photons, and that the energy and the quantity of movement conserve themselves in the course of mutual actions between these photons and the electrons or atoms. This does not mean, however, that there is no truth in the wave theory, but that energy is not transmitted by the waves. The difficult problem to solve is whether the waves serve as a guide to the photons, or if there is some other relation, at present unknown, between them.

Disappearance and Reversal of the Kerr Effect.—C. V. Raman and S. C. Sirkar. (*Nature*, 19th May, 1928, V. 121, p. 794.)

The writers announce that a beautiful confirmation of recent theories of the electric birefringence in liquids (Raman and Krishnan, *Phil. Mag.*, April, 1927) is furnished by observations of the phenomenon in electric fields oscillating with radio-frequency. Observations with octyl alcohol show that the Kerr Effect disappears at a frequency corresponding to 32 metres and re-appears at still shorter wavelengths, exactly as could be prophesied from the theories mentioned.

The Electrodeless Discharge through Gases.—J. J. Thomson. (*Proc. Phys. Soc.*, April, 1928, V. 40, pp. 79-89.)

The discharge is first defined, as a ring discharge in gas at low pressure, in which the currents form closed circuits; the method of production is given, and the theory of the discharge mathematically worked out (showing a certain analogy to the spark discharge). The author mentions that when large discharges of this kind pass through a gas, a state of the medium is obtained similar to that of the Heaviside layer. The electrodeless discharge is a convenient method for investigating experimentally the properties of such a medium; examples of such treatment are given: thus in one experiment, the number of electrons are found to be comparable with the number of molecules in the same volume. The effect of light on the discharge (due to the absorption of ultra-violet light) is studied: the effect of impurities in the gas: and finally, the effect of the discharge on chemical combination.

MISCELLANEOUS.

Die Arbeiten des Ausschusses für Schaltsbilder des Verbandes deutscher Elektrotechniker (The work of the Committee for Circuit- and Wiring-diagrams of the V.D.E.).—W. Heym. (*E.T.Z.*, 10th May, 1928, V. 49, pp. 715-722.)

This article illustrates fully the standard signs and symbols (ranging from the sign for a continuous current to that for "a power-meter for three-phase current unequally loaded with current- and voltage-transformer") arrived at by the above Committee. It also compares these standards with the work of the International Electrotechnical Commission, indicating certain differences and the reasons for them.

Drahtlose Rangierbefehlsübermittlung (Wireless shunting-control at goods stations).—K. Steinner. (*E.T.Z.*, 10th May, 1928, V. 49, pp. 722-723.)

Shunting at large goods stations is usually regulated by visual signalling, which in adverse weather conditions is unreliable and has often led to accidents. The paper outlines the wireless system already installed at a few stations in Germany.

The (Electrical) Industry as Related to Broadcasting and the Gramophone.—F. C. Topham. (*Electrician*, 11th May, 1928, V. 100, pp. 517-518.)

Among other interesting points, the author remarks that if an examination is made of the various pieces of "mains apparatus" (*i.e.*, subsidiary apparatus, for connection to the mains, for use in broadcasting reception) one is struck by the absence of "electrical design"—except in certain well-known products. Fuses are seldom provided, terminals are often close together, poorly insulated and inadequately protected against short-circuit. In the case of A.C., high secondary voltages may be employed without adequate safeguards.

Über eine Methode zur Ergeugung von Sehr Kurzen Elektrischen Wellen Mittels Hochfrequenzfunken (A method of generating very short electric waves by high-frequency spark).—E. Busse. (*Zeitschr. f. Hochf. Tech.*, April, 1928, V. 31, pp. 97-105.)

Wavelengths of the order of 30 cms. are useful in the investigation of a number of problems in theoretical and applied physics, and also lend themselves to concentration by lenses and mirrors for medical purposes. The production by valve methods presenting difficulties, other methods are being sought. The method here described uses a variation of the quenched-spark system, the primary H.F. current being supplied by a $\frac{1}{2}$ kW. valve working on 960 metres. The quenched gap is included in a closed shock-circuit to which a dipole oscillator is coupled. At least 50 watts of energy can be radiated at wavelengths of the order of 30 cms.

LES ONDES COURTES ET LES TRAVERSÉES TRANSATLANTIQUES (Short Waves and Transatlantic Flights).—*Q.S.T. Français*, April, 1928, No. 49, pp. 53-56.)

A review of the radio equipment or lack of equipment of the various machines hitherto involved in these flights, and what happened to each. The writer concludes that radio-equipment was generally provided, but in the wrong form for the purpose. He advocates the use of short waves as the only ones serviceable.

LES ONDES COURTES ET LA TÉLÉGRAPHIE SANS FIL SOUTERRAIN (Short Waves and subterranean Telegraphy).—J. M. Sacazes. (*Q.S.T. Français*, April, 1928, No. 49, pp. 57-59).

A note on the work of J. H. Rogers on buried aerials ("Undergrounds,") using powers from 5 to 1,500 watts and wavelengths between 100 and 200 metres, with the object of obtaining greater range with relatively feeble powers and without fluctuations in reception by day or night.

MARINE ET T.S.F. (The Navies and "Wireless.")—Major X. (*Q.S.T. Français*, April, 1928, No. 49, pp. 32-36.)

The principal contents are:—

Wireless and the British Navy: the use of short waves: the British Admiralty and the Washington Conference: short-wave communication between Admiralty and Hong Kong, etc. during the China troubles: typhoon-warnings by short waves in the China seas: iceberg-warnings by radio.

RADIODIFFUSION (Radio-broadcasting).—E. Girardeau. (*Q.S.T. Français*, April, 1928, No. 49, pp. 11-15.)

A manifesto by the president of the French Syndicate of Radio-electrical Industries, against the absorption of broadcasting by the State. Broadcasting should be watched over by the State just as traffic in the streets is watched over by policemen—to prevent confusion and accident. Otherwise it should be free. The State should possess its own broadcasting stations for its own purposes.

LES GRANDES HEURES DE LA T.S.F. (The great hours of "Wireless.")—Major X——. (*Q.S.T. Français*, April, 1928, No. 49, pp. 24-26).

The first part deals with interception of messages during the War, and cites as a fresh example of the "treason" of wireless the victories of Ludendorff on the eastern front, which he attributes to the interception of Russian army wireless. The second part deals with the service of wireless to humanity in the saving of life.

LES ONDES ULTRASONORES (Sound waves of ultra-audible frequency).—P. Langevin. (*Rev. Gén. de l'Elec.*, 7th April, 1928, V. 23, pp. 626-634.)

A long extract from a paper read in Paris in March, 1928. In this paper M. Langevin first defined the waves in question and pointed out the properties which give them a superiority, for certain applications, over ordinary sound waves: especially their directivity (both in transmission and in reception)—particularly useful for marine sounding, submarine detection and ship-to-ship and ship-to-shore communication. Various suggested and attempted methods of production are touched on, notably those of Richardson (who, following the "Titanic" disaster, advocated the use of these waves to detect icebergs and proposed to use aquatic organ pipes) and of Sir C. Parsons. The true solution of the problem appears to lie in the use of the piezo-electrical phenomenon to convert the easily obtained electrical oscillations of the desired frequencies into mechanical energy in the form of pressure-waves. Already, frequencies up to 160,000 p.s. have been obtained up to 1 kW., and an installation is now in preparation which will develop a power of several kilowatts. The paper goes into the application of piezo-electricity to the transmission and reception of ultra-audible waves, and then deals with certain applications, namely, marine sounding, the determination by ships of an obstacle by the method of echo: the guiding of ships in fog, and submarine communication telegraphic and even telephonic. Finally, the author refers briefly to certain applications in physiology (in regard to the destructive effect on bacteria) and in physics (as a tool for the investigation of the constitution of matter).

TÉLÉGRAPHIE OPTIQUE À ÉCOULEMENT RAPIDE DES SIGNAUX (Light-ray Telegraphy, high-speed).—F. Fournier. (*Bulletin d.L. Soc. Franc. des Elec.*, Feb., 1928, V. 7, pp. 131-135.)

A description of the author's work in evolving a simple apparatus to obtain speeds equal to those of radio-telegraphy, for day or night use, which will neither interfere with nor be interfered by other means of communication (telegraphy or telephony with or without wires). Rapid Morse signalling is produced by the two line-screens or grids, one fixed and the other vibrating, through which the light-ray has to pass. Reception is normally by telephones, a special form of selenium cell being the detector.

APPAREILS POUR LA REMISE À L'HEURE AUTOMATIQUE DES PENDULES PAR T.S.F. (Clock-setting, etc., by wireless).—M. Lavet. (*Bulletin d.L. Soc. Franc. des Elec.*, Feb., 1928, V. 7, pp. 162-177.)

The writer mentions that electric clocks can be made very cheaply which possess such accuracy that they require setting only once every six months in order to keep within one minute of exact time; these would seem to remove the need for automatic radio-telegraphic adjustment involving perhaps a special 4-valve receiver and its adjuncts. He goes on to mention, however, cases where the need still exists, and, further, he extends the use of the apparatus described to the radio-control of vehicles, ships, aeroplanes, etc., and for distress signals and explosion of mines. The scheme depends on the combination of a microphone-relay and a pendulum or balance-wheel-relay actuated by rhythmical signals. (c.f. *Wireless World*, June, 1914).

Die neuesten Fortschritte des Bildtelegraphie-Systems Telefunken-Karolus-Siemens (The latest progress of the Picture-telegraphy - system Telefunken - Karolus-Siemens).—F. Schröter. (*Telefunken-Zeitung*, Jan., 1928, No. 48-49, pp. 5-10.)

The writer begins by stating that Facsimile Telegraphy, once it reaches the word-capacity of high-speed telegraphy, is superior to Morse or "impulse" telegraphy by its avoidance of errors such as those liable to occur in tape-punching or at the receiving end. The system Telefunken-Karolus-Siemens has demonstrated its practicability in distance tests from Nauen to Ostia and Rio de Janeiro, on waves 25 m. to 60 m. Even on longer waves (800 m. between Berlin and Leipzig and 1,250 m. between Berlin and Vienna) rates between 200 and 500 w.p.m. were reached. Similar speeds were attained over open lines. On cables, the simplicity and mechanical robustness of the Karolus light relays and the abolition of relays with moving parts was found to be of especial advantage. The Telefunken photo-electric cell at the transmitter has been brought practically to perfection. Specimens of handwriting and of pictures sent by the system are included, and various details of the system are given.

The Disturbance of Radiocommunication by Tramways and its Remedies. Clausing and Muller. (*Elektrotech. Zeitschr.*, 21st February, 1928, V. 49, pp. 178–180.)

Interference caused by sparks between collector and line can make themselves felt at a distance of 4 km. The paper recalls previous remedial work in Germany and describes the most recent researches. The use of a material which gives an arc and not a spark even at the lowest voltages met with, for the current-collector, is recommended. Carbon is indicated as the suitable material.

Enkele Physische Beschouwingen over Ultra-Korte Golven, Mede in Verband met de Uitzendingen van het Philips' Radio-Laboratorium (Some physical considerations on ultra-short waves based on transmissions from the Philips' Radio Laboratory). —B. Van der Pol. (*Tijdschr. v. h. Ned. Rad.*, April, 1928, V. 3, pp. 161–184.)

The author deals with the history of ultra-short wave development, and passes on to a consideration of various points inherent in the use of these waves: *e.g.*, skin effect and the need for maintaining constancy of wave length (by piezo-electric or other methods). The propagation of the waves is then considered, and the work of Breit and Tuve in Washington ("echo" effect), Appleton and others is referred to. The waves in question are of the order 12 to 30 metres. The author mentions that an example of the other kind of "echo" effect (dependent not on the difference in paths of the direct and reflected rays, but on the circumnavigation of the earth) was produced when a metronome beating seconds was placed before the microphone of the Philips' Laboratory transmitter, and the receiving station heard not merely double but treble beats, showing a double circling of the earth.

Air Service and Amateur Co-operation (The American Coast-to-Coast Air Route Described.)—H. de A. Donisthorpe. (*Wireless World*, 9th May, 1928, V. 22, pp. 491–492.)

Joint Meeting of the Institution of Electrical Engineers and the American Institute of Electrical Engineers.—(*Bell Tech. Journ.*, April, 1928, V. 7, pp. 161–167.)

A verbatim report of the joint meeting of these two Institutes, by transatlantic wireless telephone, on February 16th, 1928—the first of its kind.

The Use of a Moving Beam of Light to Scan a Scene for Television.—F. Gray. (*Journ. Opt. Soc. Amer.*, March, 1928, V. 16, pp. 177–190.)

A description of this portion of the system of television developed recently by the Bell Telephone Laboratories. The paper, however, begins by a brief survey of the former systems (in which what is "scanned" is an image of the subject formed by a lens) and of the Bell System (in which the subject itself is scanned by a moving beam) and compares the two systems: the latter presenting two very large gains in the amount of light that can be collected to produce photo-electric currents—the transient nature of the illumination permits it to be very intense without causing inconvenience to the subject, and the optical efficiency of the system is not limited by the aperture of a lens, but can be increased by using large photo-electric cells and more than one in parallel.

Les Stations de Signaux Horaires. (Time-Signal Stations.)—De la Forge. (*Q. S. T. Français*, May, 1928, V. 50, pp. 5–11.)

The present instalment deals very fully with the twelve European stations and their various methods. A complete table is given.

Dynamo Unipolaire Poirson.—(*Rev. Gen. de l'Elec.*, 28th April, 1928, V. 23, p. 730.)

The French National Office for Scientific and Industrial Research includes, among the various inventions in which it is interested, the construction of a large unipolar dynamo (for D.C. without commutator) to give 10,000 ampères at 10 volts.

Les Reproducteurs Électriques de Phonographie (Electric "Pick-Ups" for gramophones, etc.).—A. Cremailh. (*Q.S.T. Français*, May, 1928, pp. 48–56.)

Among other interesting points in this article may be mentioned an outline of an electrical process for record-making depending on an oscillograph-record combined with pantograph-magnification; a suggestion that electric reproducers cause less wear on the record because less work has to be done by the disc; and a suggestion that an electro-static pick-up (in which the part moving with the needle forms one plate of a condenser) can eliminate needle-scratching noises more than the usual electromagnetic pick-up.

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPRECOJ DE CIRKVITOJ.

La Ekvivalenta Indukteco kaj Kapacito de Anteno.

Redakcia artikolo diskutanta esprimojn por la indukteco kaj kapacito de anteno. Oni aludas al esprimoj por ĉitiuj kvantoj donitaj en la " Jarlibro de Senfadena Telegrafio " 1917a kaj al esprimoj donitaj en lastatempa verko " Senfadenaj Principoj kaj Praktikado " de D-ro. L. S. Palmer.

La esprimoj estas derivitaj el unuaj principoj kaj la kialo estas montrita por la erara rezulto obtenita de D-ro. Palmer.

Reaktancaj kaj Admitancaj Kurvoj Aplikitaj al Agorditaj Cirkvitoj kun kaj sen Rezisteco.—L. T. Bird.

En la unua parto de l'artikolo la aŭtoro diskutas la ekzemplon de cirkvitoj sen rezisteco, kaj donas kurvojn de la reaktanco kaj la admitanco de kapacito kaj indukteco. Kombinoj de indukteco kaj kapacito estas poste simile konsideritaj, kiam ĉi tiuj estas konektitaj simple serie, simple paralele, kaj ankaŭ en pli komplikitaj cirkvitoj, k.e., cirkvitoj kun branĉoj, miksitaj seriaj kaj paralelaj, k.t.p.

La dua parto de l'artikolo diskutas resonancajn cirkvitojn kun rezisteco, traktante unue pri l'ekzemplo de kurento restanta konstanta, dum la frekvenco varias, kaj poste de tensio restanta konstanta dum la frekvenco varias. La ekzemplo de rezisteco paralele kun kondensatoro estas poste konsiderita kiam la tuto de kurento kaj tensio respektive restas konstantaj.

La artikolo estas bone ilustrita per grafikaĵoj kaj vektoraj diagramoj, kaj estas finota en la venonta numero.

Pri Aroj da Paralele-aranĝitaj Valvoj Provizantaj Rezistivajn Ŝarĝojn sen Distordo de la Onda Formo.—W. Baggally.

La aŭtoro traktas longe la kondiĉojn plenumotajn de aro da valvoj provizantaj potencon sen distordo de onda formo, ĉi tiu parto de la prelego estante pure matematika kaj ne permesante resumigon.

La rezonado estas poste aplikita al kelkaj praktikaj ekzemploj, kiel ekzemple, la potenco havebla ĉe iuj difinitaj konstantoj ; la valoro de ŝarĝa rezisteco por maksimuma potenco ; la nombro da valvoj bezonitaj por provizi difinitan potencon, k.t.p.

Amortizo Kaŭze de Krada Kurento Rilate al Valva Oscilatoro.—M. Reed.

La artikolo konsideras kuplitan oscilatoron kun la anoda cirkvito agordita, kaj montras la kalkuladon de l'amortizo enkondukita en la oscilan cirkviton kaŭze de krada kurento.

La rilatoj inter anoda alternkurento kaj krada tensio estas konsideritaj, kaj la efekto de krada kurento montrita grafike. La kalkulado estas poste farita pri aparta okazo, kiam la potenco absorbita en la krada cirkvito estis 0.1233 vato, ĉi tio estante la ekvivalento de efektiva rezisteco de 44 omoj enkondukita en la anodan cirkviton.

Mallongondaj Antenaj Sistemoj. Elementa Teorio pri la Sendado de Altfrekvenca Energio laŭlonge de la Alkondukiloj.—E. Green.

La aŭtoro unue konsideras la ekzemplon de ebena elektromagneta ondo en spaco inter du paralelaj kaj perfekte kondukantaj ebenoj je iu ajn distanco apartaj, kaj montras, ke la ekzemplo de senlime longa alkondukilo de nekonsiderinda rezisteco kaj elfluo donas analogajn rezultojn.

Li poste diskutas la rilatojn de kurento, tensio, kaj energio, en la onda lameno en la alkondukilo kun sinusa elektromova forto aplikita al la enmetaj bornoj, kaj kun diversaj bornaj ŝarĝoj egalaj kaj malegalaj je la ondega impedanco de l'alkondukilo. La kondiĉoj en la ŝarĝo kaj ĉe punktoj en la alkondukilo estas ekzamenitaj kaj ilustritaj per vektoraj kaj grafikaj diagramoj, kaj la efekto de mallonga cirkvito aŭ de malferma cirkvito ĉe l'elmetaj bornoj estas diskutita. Laste konsiderita estas la efekto de maldensiĝo.

RICEVADO.

Valvoj kun Skrenitaj Kradoj.

Resumo de neformala diskutado ĉe kunveno de la Senfadena Sekcio de la Institucio de Elektraj Inĝenieroj, Londono, je 2a Majo, 1928a.

La diskutado estis malfermita de S-ro. M. G. Scroggie, kiu pritraktis la evoluiĝon de la valvo kun skrenita krado, kaj ĝian aplikadon, precipe al altfrekvenca amplifado.

La diskutado estis daŭrigita de D-ro. J. Robinson, S-ro. C. F. Phillips, Leŭt.-Kol. K. Edgeworth, Kap. P. P. Eckersley, S-ro. E. H. Shaugnessy, Leŭt.-Kol. Fuller, kaj aliaj, kaj S-ro. Scroggie respondis al kelkaj el la punktoj levitaj de la aliaj parolantoj.

La Ŝajna Malmodulo de Malforta Stacio per Pliforta Stacio.—R. T. Beatty.

La aŭtoro unue konsideras la fortecon de portondo ricevita el agordita signalo dezirita kaj el nedezirita signalo malagordita ĝis, ekzemple, 50 k.c. Li konkludas, ke la elimino de ĉi tiu lasta estas kaŭze de interago inter la signaloj, kiun oni ne enkalkulas je simpla cirkvita teorio. Li poste ekzamenas la supersonajn batojn naskitajn inter la du portondoj, kaj montras, ke ili estas ankoraŭ modulitaj per la modulo de la dezirita signalo. Li plue montras, ke per perfekta detektoro, la nedezirita signalo povus esti tute malmodulita de la pliforta dezirita stacio, sed, ke per neperfekta detektoro, iometa modulado, pro la plimalforta nedezirita signalo, estus ricevita. La efektoj estas analogaj al supersona ricevado, kiam la aŭda komponero estas portita sur nova supersona portondo kaj estas izolebla nur per trapasigo tra dua detektoro.

Li konkludas, ke ĉe praktikado, la nedezirita stacio povas esti silentigita se ĝia portondo ne superas dekonon de la nedezirita stacio, laŭ mezuro ĉe la krado de l'detektora valvo.

HELPA APARATO.

PUNKTO-KUNFORĜITAJ TERMO-KUNIĜOJ.

Mallonga priskribo kun fotografaĵoj estas donita pri modelo de vakua termo-kuplilo de ferokonstantano punkto-kunforĝita al la varmiga fadeno de nikromo, plateno, aŭ konstantano.

Per ĉi tiu speco de kuniĝo estas malpli da ŝanco, ke la kuplilo enhavos malgrandan longon de l'varmiga fadeno, dum ĝi estas malpli impresebla je domaĝo pro troŝarĝado.

La kuniĝoj estas fabrikitaj de S-roj. Collier kaj Stephenson, Hornsey, Londono.

SUB-NORMA ONDOMETRA DESEGNADO.—W. H. F. Griffiths.

Krom precizeco de normigado, la aŭtoro emfazigas la bezonon por *konservi* ĉi tiun precizecon kaj urĝas la utiligon de altaj valoroj de kapacito.

Li poste diskutas la desegnon de mallongonda ondometro, kun skalo malsupreniranta ĝis 10 metroj, kiu utiligas ne malpli ol 240 $\mu\mu$F. Precizeca variebla aerkondensatoro estas uzita kun du tre kompaktaj fiksaj aerkondensatoroj. Rigida memsubtenanta bobeno kun unu turno de kupra tubo estas uzita kiel la induktanco malsupreniranta ĝis 16 metroj. Por utiligo malsupren ĝis 10 metroj, bobeno de noveca desegno estas uzita, konsistante el nombro da maldikfadenaj cirkvitoj konektitaj paralele per du pezaj koncentraj rondaj ĉef-fadenoj. La konstrumetodo de l'bobeno estas ilustrita.

DIVERSAĴOJ.

RESUMOJ KAJ ALUDOJ.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

GRAFIKA KALKULADO.—M. H. Ashworth.

La aŭtoro diskutas grafikajn metodojn por fari la normigadon de Moullin'a (anodkurva) voltmetro laŭ la kontinukurentaj karakterizoj de la valvo. Volto-tempaj kurvoj estas aldonitaj al la karakterizo, laj la grafika derivado de la kurento-tempaj kurvoj montritaj. Grafika metodo por trovi la areon de ĉi tiuj kurvoj estas poste klarigita, kaj oni montras, ke bona interkonsento estas obtenita kun la rezultoj, kiel mezuritaj de planimetro.

Aliaj aplikadoj de la metodo estas cititaj.

LIBRO-RECENZOJ.

Recenzoj estas donitaj de la jenaj verkoj :—

PITMAN'S TECHNICAL DICTIONARY (Teknika Vortaro) en Sep Lingvoj.

WIRELESS PRINCIPLES AND PRACTICE (Senfadenaj Principoj kaj Praktikado), de L. S. Palmer, M.Sc., Ph.D.

THE INSTRUMENT WORLD (La Instrumenta Mondo), nova ĵurnalo por desegnistoj, k.t.p.

INTERMEDIATE ELECTRICITY AND MAGNETISM (Mezgrada Elektro kaj Magnetismo), de R. A. Houston, M.A., D.Sc.

Some Recent Patents.

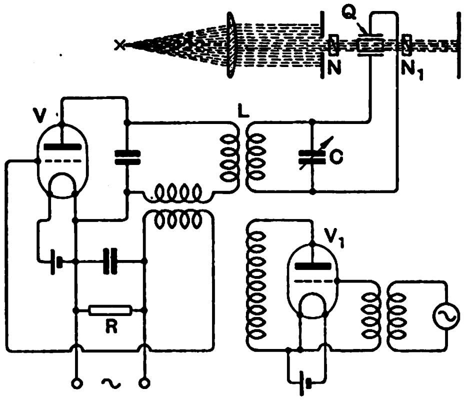
The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

TRANSMITTING PICTURES.

(*Convention date* (*Germany*), *1st March,* 1926. *No.* 266753.)

When rays of light are passed through a doubly refracting crystal, they are subject to variations as regards the condition of polarisation and direction of propagation, so that for a given type of crystal and light employed an extinction of rays of a given wavelength may be secured. In this way the intensity or colour of light passing through the system may be controlled.

The invention consists in utilising such variations in the optical qualities of a quartz oscillator, in combination with its normal piezo-electric property of mechanical vibration at definite frequencies. As shown in the figure, a ray of light from a source S, the intensity of which is to be controlled, for example, by the incoming currents from a picture-transmission system, is passed through an optical system comprising crossed Nichols N, N_1 and a piezo-electric oscillator Q of quartz, Tourmaline, or Rochelle salt. The crystal is set into vibration at its fundamental frequency, or an harmonic thereof, by means of a tuned circuit L, C, connected across its terminals and energised by an oscillating valve V. The incoming signals to be converted into corresponding light-effects may be applied either across a resistance R in the grid circuit of the oscillator R, or alternatively to the grid circuit of a separate amplifier V_1.

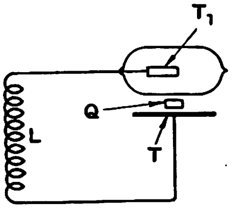


Patent issued to The Telefunken Co.

LUMINOUS CRYSTAL OSCILLATORS.

(*Convention date* (*Germany*), *2nd September,* 1926. *No.* 277002.)

It is known that when a piezo-crystal is oscillating at a fundamental frequency, small sparks may be caused to appear on the surface of the crystal when situated in a strong magnetic field. Usually, however, the crystal breaks up when the sparks exceed a certain length, or the applied tension grows too high. The effect can be more favourably observed if the crystal is mounted inside an evacuated tube, but this method is inconvenient in practice.



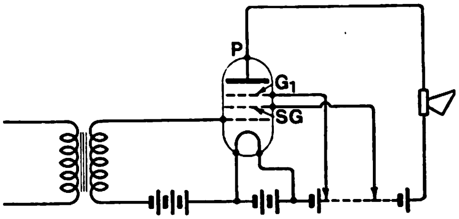
The inventor has discovered that the desired luminous effect can be obtained simply by mounting the crystal in close proximity to a tube filled with helium, neon, or argon gas. As shown in the figure, the crystal Q is located between an external electrode T and a second electrode T_1 mounted inside the tube. When a frequency to which the crystal is resonant is applied across the coil L, luminous effects appear. The phenomenon can be utilised either as a convenient method of determining the frequency of a crystal under test or, conversely, to measure the frequency of a given source of oscillations.

Patent issued to H. Eberhard.

SCREENED GRID AMPLIFIERS.

(*Application date,* 24*th December,* 1926. *No.* 287958.)

When using a screened grid valve for power amplification, owing to the considerable fluctuations of anode potential created by large current-variations in the output circuit, it may happen that the effective voltage of the anode will drop below the normal positive bias applied to the screening grid.



In these circumstances secondary emission is liable to occur between the two electrodes in question, together with temporary reversals in the normal direction of the electron stream, both of which factors tend to diminish the overall efficiency of the valve.

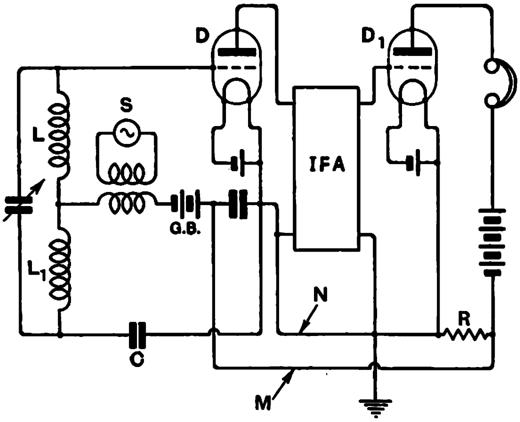
In order to overcome this tendency a second auxiliary grid G_1 is inserted, as shown, between the usual screening grid *SG* and the anode *A*, and is supplied with a biasing voltage well below that of the screening grid. Under these circumstances the instantaneous voltage of the anode can never fall materially below the level at which "reversal" tends to set it.

Patent issued to N. V. Philips Gloeilampenfabrieken.

AUTOMATIC VOLUME CONTROL.

(*Application dates, 1st and 3rd January,* 1927. *No.* 287972.)

The figure shows in schematic form a superheterodyne receiver comprising a frame aerial *L*, L_1, a source *S* of local oscillations, a first detector *D*, and an intermediate-frequency amplifier *IFA* followed by a second detector. Input signals are applied from the upper half *L* of the centrally-earthed frame aerial, the lower winding L_1 and condenser *C* functioning to stabilise the system.



A resistance *R*, serving to apply an automatic control of signal strength, is inserted in the output circuit of the last valve D_1, and also in the direct-current connection between the filament and grid of the first valve *D*, through leads *M*, *N*.

The value of resistance *R* and grid bias *GB* are adjusted so that (1) the detector *D* operates on the point of greatest curvature of its characteristic curve and (2) the peak voltage from the heterodyne source *S* will be such as to raise the operating characteristic to saturation point.

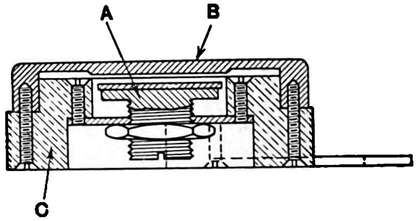
Under these circumstances a decrease in the incoming signal strength—due, for instance, to fading, lowers the plate current from the valve D_1 and hence the voltage drop across the resistance *R*. This in turn shifts the operating point of the first valve *D* to a more sensitive part of the curve, and also causes an increase in the effective heterodyne voltage, thus tending automatically to restore signal strength. Should the signal voltage increase above normal, the action of the resistance *R* is reversed.

Patent issued to Standard Telephones and Cables.

MOUNTING PIEZO CRYSTALS.

(*Convention date* (*U.S.A.*), 13*th September,* 1926. *No.* 277330.)

A crystal holder, specially adapted for mounting piezo oscillators, comprises an adjustable screw-controlled electrode *A*, protected by an outer cup-shaped electrode *B* firmly screwed on to a baseplate *C* of suitable insulating material. The quartz or other crystal is mounted on the central electrode *A*.



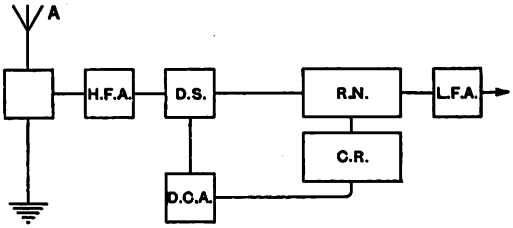
A long leakage path is maintained between the two electrodes, whilst metals having a low coefficient of expansion are used for the conducting parts. The holder protects the crystal from dust and dirt, whilst the effect of temperature variations is minimised, as far as possible, so as not appreciably to alter the electrode spacing and consequently the effective capacity value of the unit in operation.

Patent issued to Westinghouse Electric Co.

COMBINED LAND-LINE AND RADIO SYSTEMS.

(*Application date, 7th January,* 1927. *No.* 288,371.)

When wireless signals are relayed from the aerial for some distance over a land line, varying attenuation in the ether (due to fading and similar causes) is liable to give rise to considerable fluctuation in the effective strength of the signals as received at the terminal recording station. For instance, the amplitude of the low-frequency component of speech signals at the output of the first amplifier may vary between 1 and 50 milliamps, so that the repeater valves used on the land line may be over-loaded, or other causes of distortion may arise.



In order to prevent this an automatic limiting or regulating device is inserted between the receiving aerial and the land line which operates as follows. The incoming signals are fed from the aerial *A* to a high-frequency amplifier *HFA* and then to a detector *DS*, where the low-frequency signal current is separated from the direct-current component. The former is passed through an attenuation network *RN* comprising a number of resistance units arranged in chain form, the number of units in series being controlled by means of switches actuated by means of a master relay *CR*.

The relay *CR* is controlled in turn by the direct-current component derived from the detector *DS* and amplified at *DCA*. The strength of the control current supplied to the relay *CR* will be proportional to the amplitude of the received carrier wave, and assuming that this bears a constant relation to the signal strength, the operation of the relay *CR* can readily be arranged to maintain a constant overall input to the land-line amplifier *LFA*, irrespective of fluctuations in the aerial voltage due to fading and similar causes.

Patent issued to G. A. Mathieu.

AUTOMATIC DIRECTION-FINDING.

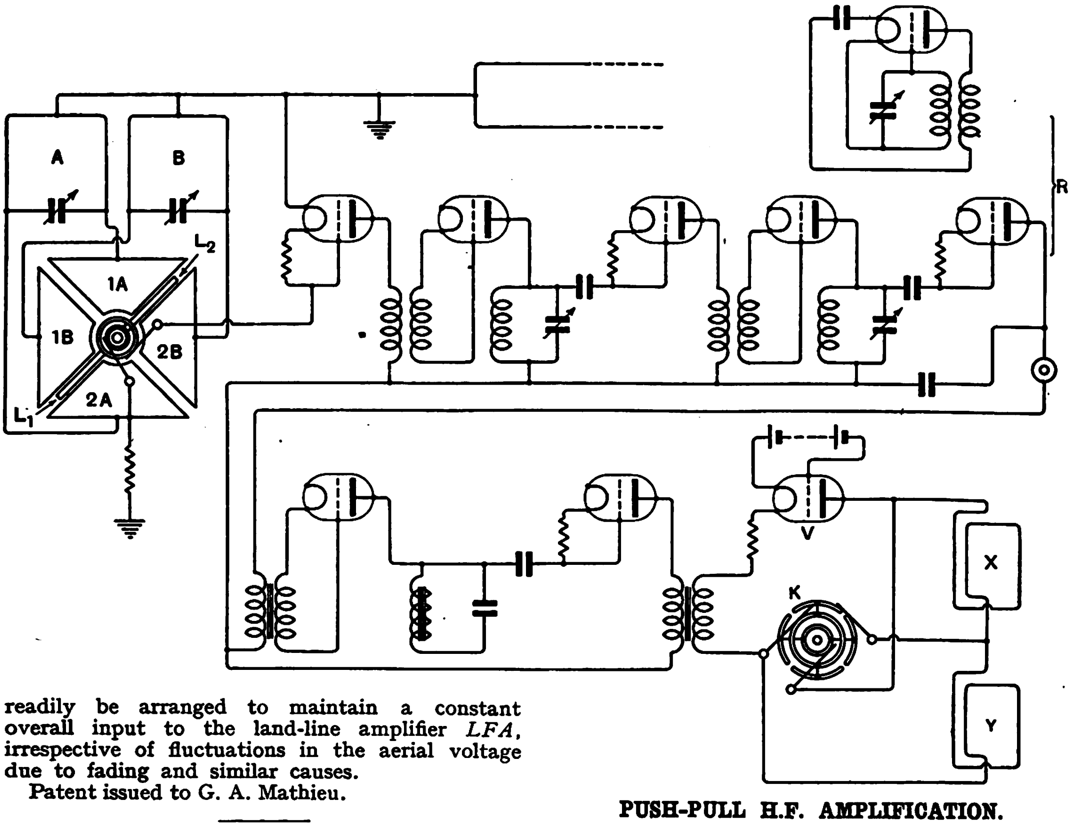
(*Application date, 25th January,* 1927. *No.* 286840.)

The arrangement is adapted to give an automatic indication of the direction of an incoming signal. Two frame aerials *A*, *B* are mounted at right angles to each other in the ordinary way, the output terminals being taken to opposite pairs of a series of four fixed plates marked 1A, 2A, 1B, 2B respectively. The midpoints of the aerials are earthed as shown.

Between the fixed plates are mounted two series of continuously rotating plates L_1, L_2. The plate L_1 forms a capacity coupling between the aerials *A* amd *B* and the input of a superheterodyne receiver *R*. The plate L_2 merely completes the symmetry of the frame circuits through a resistance R_1 to earth.

The automatic indicator consists of a moving needle (not shown) controlled by the current flowing through two coils *x*, *y*. By means of a commutator device *k*, which is driven from the same shaft as the rotating plates L_1, L_2, the coils *X*, *Y* are coupled intermittently to the last amplifier *V* of the set, and are thus fed with direct current proportional at all times to the " pick-up " of the loop aerials *A*, *B*, so that the moving needle automatically registers the direction of the received signals.

Patent issued to H. Busignies.

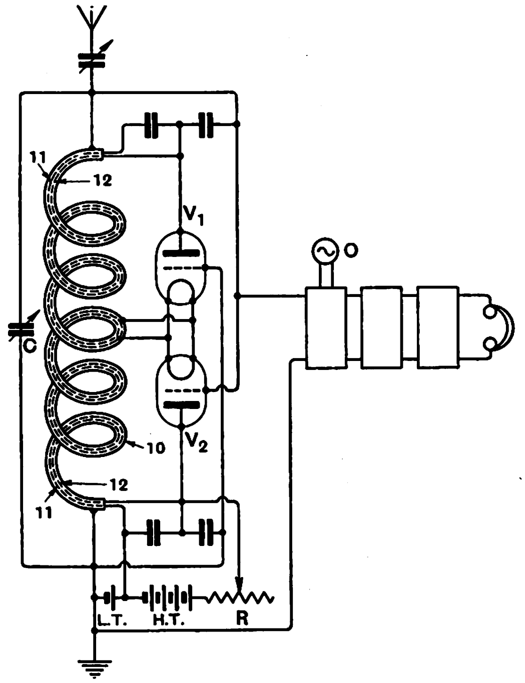


PUSH-PULL H.F. AMPLIFICATION.

(*Application date, 10th January,* 1927. *No.* 288,379.)

For short-wave reception, a coil 10 of copper tubing shunted by a tuning condenser *C*, forms the aerial inductance. The tubular coil 10 encloses insulated wires 11 and 12, the outer ends of the latter being connected to the plates of two valves V_1, V_2, through a high-tension battery *HT*, and a resistance *R*, which serves to regulate the degree of reaction.

The upper and lower ends of the coil 10 are connected to the respective grids of the valves V_1, V_2, whilst the centre point is tapped as shown to the common filament. The other side of the filament is connected to the wire 11, this and the coil 10 serving to supply filament current from the battery *LT*. The upper half of the coil 10 applies the incoming signal voltages across the grid and filament of valve V_1, whilst the valve V_2 is similarly fed from the lower half of the same coil so that the valves operate as push-pull amplifiers in a regenerative circuit of the Hartley type. The amplified signals are then combined with a local oscillator *O* forming part of a standard superheterodyne receiver.



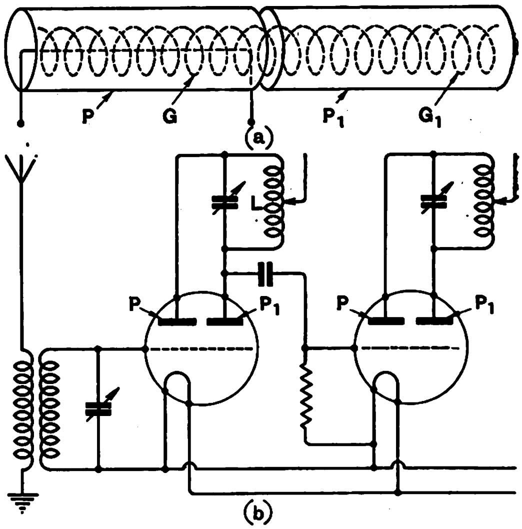
Patent issued to Standard Telephones and Cables, Ltd.

MULTI-ELECTRODE VALVES.

(*Application date, 30th November,* 1926. *No.*288,663.)

In order to balance-out inter-electrode capacity effects, a valve amplifier is provided with extra plate or grid elements so disposed as to lie outside the normal electron stream and to function merely as a condenser coupling between the plate and grid circuits. In the construction shown in Fig. A, the normal assembly of filament *F*, grid *G*, and cylindrical plate *P* is supplemented by a symmetrical plate P_1, placed close to but insulated from the plate *P* and surrounding an extension G_1 of the spiral grid, which lies outside the path of the electron-stream from the filament *F*.

Fig. B shows the circuit arrangement of a two-stage high-frequency amplifier using balanced valves of this type. The divided plate *P*, P_1 is shunted by a tuned circuit *LC*, the high-tension supply being tapped to the centre of the coil *L*.



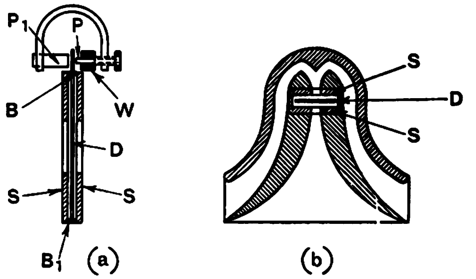
The undesired capacity-coupling existing between the "active" grid and plate *P* is now counterbalanced by the condenser of identical value formed by the symmetrical counterpart P_1, G_1.

Patent issued to J. Robinson.

LOUD-SPEAKERS.

(*Application date,* 19*th January,* 1927. *No.* 288,386.)

A band-shaped diaphragm *D*, Fig. A, is supported inside a slotted sound-box *S* by a fixed bearing at *B* and by a lower bearing B_1 arranged to permit of a slight longitudinal movement. Between these points the diaphragm is unrestrained. A part of the diaphragm extends freely beyond the upper bearing *B* and passes between the two polepieces of the actuating electromagnet. One polepiece *P* is thinner than the other P_1 and carries the speech coil *W* as shown. The slot in the sound box *S* may be arranged inside a double-horn, as shown in Fig. B.



Patent issued to H. Sachs.

EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. V. AUGUST, 1928. No. 59.

Editorial.

Quality *versus* Selectivity in Distant Broadcasting Reception.

IN the March number of the Proceedings of the Institute of Radio Engineers a paper is published which was read by Mr. F. K. Vreeland and discussed at a recent meeting of the Institute. It is entitled, "On the Distortionless Reception of a Modulated Wave and Its Relation to Selectivity." The problem is summarised in the following terms: "Selectivity requires that a certain group of radio frequencies, comprising a modulated signal wave, must be separated from all other radio waves. Fidelity requires that all the frequencies included in the transmitted wave must be received in their true relative proportions. These two conditions give rise to a peculiar and highly specialised problem of receiver design, namely, to construct a selective system that is equally responsive to all frequencies within a given range or band and unresponsive to frequencies outside this band. The condition of crowded air channels requires a very sharp cut-off at the edges of the band."

The transmitting station actually sends out waves of one definite frequency, but of varying amplitude and such a modulated wave has the same effect on the receiver as waves of constant amplitude but of different frequencies, the different frequencies covering a range on either side of the actual frequency of the wave. If we take 10,000 cycles per second as the highest audible frequency which we need consider, then for this case, the amplitude of the current in the transmitting aerial will vary in amplitude 10,000 times per second, which will have the same effect on the receiving apparatus as if three waves of unvarying amplitude were being received, one having the nominal frequency f of the transmitter, one a frequency $f + 10,000$, and the other $f - 10,000$. If all the audible frequencies are to be received in their true relative proportion the receiver must respond uniformly to all frequencies within a band of 20,000 cycles per second. The absence of frequencies above about 10,000 would perhaps be detected by a very critical listener in the distinctive timbre of high notes on the violin, oboe, piccolo, etc. This refers to steady oscillations; the absence of the higher frequencies may affect the transient phenomena associated with percussion instruments and certain speech consonants. Setting 10,000 as our limiting audible frequency, the requirement of selectivity, *i.e.*, of non-interference from any wave outside our band, would best be met by a rectangular response curve. By this we mean that if our receiver is acted on by a wave of constant amplitude, the frequency of which is gradually changed, the receiver should give no response except over a band 20,000 cycles wide, and uniform response within this band. Now, an ordinary tuned circuit gives a response curve approximating more closely to a triangle than to a rectangle if it is made highly selective, with the result that the higher audible frequencies are not reproduced to the same extent as the lower ones. If to minimise this defect, the damping is increased, then the response curve broadens out into a wide hump and neighbouring wavelengths cause interference, to say nothing of the sacrifice of sensitiveness.

In the paper referred to, Vreeland discusses two methods of overcoming the difficulty, but unfortunately the treatment is very popular and little or no attempt is made to submit the proposals to vigorous mathematical or experimental examination. Both methods employ well-known devices to obtain an approximation to the rectangular response curve. A device which has such a characteristic is known as a band-pass filter. A band-pass filter consists of a cascade of tuned oscillatory circuits, each unit being coupled both to the preceding and following unit. Every wireless receiving set with more than one tuned high-frequency circuit may be regarded as a band-pass filter; even a single tuned circuit constitutes a primitive band-pass filter.

If one has two low-loss oscillatory circuits in cascade with loose coupling between them, the selectivity can be made very great by tuning them both to the same frequency, but the response will fall off very rapidly with increasing audio frequency. Now, there are several ways in which, by sacrificing selectivity—and sensitivity—the response can be made more uniform over the audible range. One method is to insert damping in each oscillatory circuit; two or three damped circuits in cascade give a much closer approximation to the desired rectangular response curve than a single low-loss circuit. There is, of course, a loss of sensitivity which has to be made up for by inserting amplifying valves between successive high-frequency stages. The use of two or three stages of high-frequency amplification is not always a sign that the set is intended to receive very distant stations, but more often that it is designed to give selectivity and quality on moderately distant stations. The reverse phenomenon occurs when a set is made super-sensitive by the use of excessive reaction; the super-sensitiveness is confined mainly to the carrier wave with the result that the quality is poor.

There is another method by which the response of a cascade of two low-loss circuits can be made more uniform over the audible range—again with a sacrifice of selectivity and sensitivity—and that is by the simple expedient of detuning them, one above and the other below the carrier frequency. If there are three circuits, then one can be left in tune. This is one of the methods advocated by Vreeland, but we presume that everyone who has experimented with a set in which this detuning is possible has adopted it when the reception was strong enough to allow of it. Vreeland proposes, however, to put the circuits out of tune in a definite ratio by adding fixed inductances, and leaving the condensers gang controlled.

The alternative method suggested by Vreeland consists in keeping the two oscillatory circuits tuned, but coupling them so closely together that the well-known double hump just appears in the resonance curve. This method is really very similar to the previous one since when two similar oscillatory circuits are coupled, they cease to have their individual resonant frequency, but the combination exhibits two resonant frequencies differing by an amount depending on the tightness of coupling.

We suggest as an interesting problem the theoretical investigation of the relative merits of the three methods of achieving the desired result. It is interesting to note that, in each case, what is usually regarded as a defect is deliberately introduced; in the first case, damping is introduced into the tuned circuits; in the second, the gang-controlled circuits are deliberately detuned; in the third, the coupling is made so tight that the double hump appears.

G. W. O. H.

Inter-Electrode Capacities and Resistance Amplification.

By L. Hartshorn, A.R.C.S., B.Sc., D.I.C.

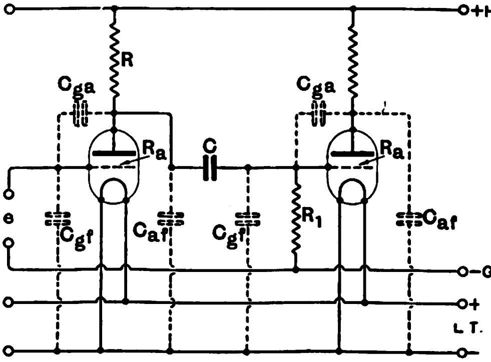
(The National Physical Laboratory.)

RECENT developments in resistance amplification have been towards the use of high voltage factor valves, and high anode resistances. A general discussion of this matter, particularly of the use of very high anode resistances, was given by F. M. Colebrook some time ago in this journal (*E.W. & W.E.*, April, 1927, p. 195). Mr. Colebrook showed that when moderate anode voltages are used (say 50 to 100 volts), the "working characteristic" of the valve-anode resistance combination will be a straight line provided that the anode resistance R is large compared with the internal resistance of the valve R_a, and therefore, in order to avoid distortion, this condition should be fulfilled. It was further pointed out that in multi-stage amplifiers, certain of the inter-electrode capacities of the valves act as shunts across the anode resistances, and the effect of this is to cause the impedance of the anode circuit to vary with the frequency, thereby causing distortion. This effect is larger, the larger the value of the anode resistance, and the choice of a suitable anode resistance is a matter of compromise. A high value is required in order to keep the "working characteristic" straight, and also to make the amplification per stage approximate to that of the voltage factor of the valve used, but the value must not be so high that the shunting effect of the electrode capacities causes considerable distortion.

In a subsequent letter (*E.W. & W.E.*, June, 1927) Mr. Colebrook emphasised the fact that his analysis of the coupling conditions in the resistance amplifier was valid only under the conditions stated, viz., that the shunting effect of the electrode capacities of the valves on the various resistances was small, whereas from measurements of the input impedance of valves made by the writer, it appears that the effective values of the capacities of valves may reach values as high as 100 $\mu\mu$F. in the case of an ordinary R valve, and that valves with a high voltage factor may be expected to possess even higher effective values, under the conditions obtaining in a resistance amplifier. Further, Mr. Colebrook drew the attention of the writer to the importance of making measurements of the input capacities of valves of high voltage factor, and of investigating the bearing of the results on the limitations of resistance amplifiers. This article is the outcome of these suggestions.

Input Impedance, Admittance and Capacity.

Fig. 1 (taken from Mr. Colebrook's article previously referred to), represents a two-stage resistance amplifier of the usual type.



giF. 1.—*Two-stage resistance amplifier.*

In order to prevent inter-electrode capacities from being overlooked, these are indicated by dotted lines and lettered C_{ga}, C_{gf}, etc. Here C_{gf} represents the electrostatic capacity between the grid and the filament of a valve. This is a quantity which can be measured fairly easily, and is known to be of the order 5 to 10 $\mu\mu$F. Thus on tracing out the network, one is tempted to believe that the grid leak R_1 is shunted merely by a capacity of this order. From one point of view, however, diagrams of this nature showing inter-electrode capacities are incomplete. We are apt to assume that these capacities are carrying currents which can be determined by a simple application of Ohm's Law (in the generalised form used in alternating current work $V = IZ$), that is, they can be regarded as ordinary electrostatic capacities, linking up the appropriate points of the network. This is only partially true. The diagram is defective (from the point of view of analysing the behaviour of the circuit) inasmuch as there is nothing in it to represent the amplifying properties of the valves, and as the effective values of certain of these capacities may also be considered to be amplified, the point is one of importance. A diagram intended to represent completely the behaviour of a valve should take the form shown in Fig. 2. Here *F*, *G* and *A* are the filament, grid, and anode respectively. They are connected by the inter-electrode capacities. R_a represents the internal resistance of the valve, and *Z* is the external impedance added in the anode circuit. The amplifying properties of the valve are represented by an E.M.F. in series with the resistance R_a, of magnitude μe, where μ is the voltage factor of the valve, and *e* is the alternating component of the P.D. between the grid and filament. If the direction of *e* is such as to make the grid more positive, then the E.M.F. μe must be in the direction which will cause an increase in anode current, *i.e.*, it must drive current through the resistance R_a in the direction *A* to *F*, as in the diagram. (The anode current consists of negative electrons passing from *F* through R_a to *A*, and this is the equivalent of positive electricity passing from *A* to *F*.) It should be mentioned here that this diagram only applies to valves in which sufficient negative grid bias is used to make the grid-filament conductance negligibly small. Also it only represents the behaviour of the valve with respect to small alternations of applied voltage. Within these limitations a two-stage resistance amplifier may be completely represented by Fig. 3. It should be noticed that the grid leak R_1 is shunted, not merely by the capacity $G'F'$, but by the whole network lying to the right of $G'F'$, including the E.M.F. $\mu e'$. The resultant shunting effect is determined by the magnitude of the grid current $i'g$, and this is determined by the input admittance $A_g' = i_g'/e'$, or by the input impedance $Z_g' = e'/i_g'$ of the second valve. It will now be shown that the input admittance of such a valve is much greater than that of the grid filament capacity $G'F'$, which is, of course, given by $jC'_{gf}\omega$, where *j* is the operator rotating through a right-angle, and $\omega = 2\pi \times$ frequency.

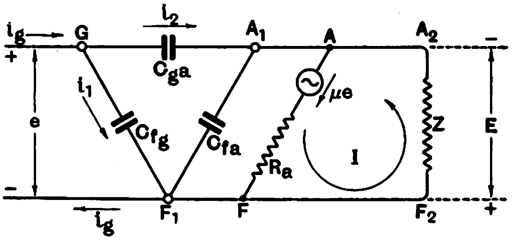


Fig. 2.—*Equivalent network for single valve.*

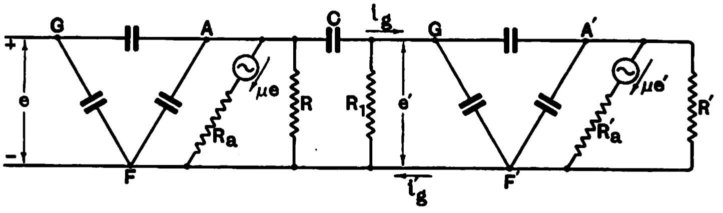


Fig. 3.—*Equivalent network for two-stage resistance amplifier.*

Refer again to Fig. 2, which is the network equivalent to a single valve, of voltage factor μ, and internal resistance R_a, with an impedance *Z* in the anode circuit, *e* being the alternating component of the P.D. between filament and grid. i_g is the alternating component of the grid current, *i.e.*, the current entering the valve at *G* and leaving at *F*. This current, entering at *G*, may be considered as dividing into two components, i_1 passing through the capacity C_{gf} to *F*, and i_2 passing through the capacity C_{ga} to *A*, where it again divides, finally reaching *F* by the three paths C_{af}, R_a and *Z* in parallel.

Evidently, $i_g = i_1 + i_2$, and if we can calculate the magnitude of the currents i_1 and i_2, the grid current i_g will be known. Now the P.D. across the condenser C_{gf} is *e*, and therefore the current i_1 carried by this condenser must be

$$i_1 = je.C_{fg}\omega \quad .. \quad .. \quad (1)$$

Let *E* be the alternating P.D. produced by the valve across the impedance *Z*, so that

$k = E/e$ is the actual amplification of voltage produced by the valve. The current through Z, which gives rise to the potential difference E, is driven by the E.M.F. μe, and therefore flows in the direction A, F, F_2, A_2. Thus the direction of E must be such as to make the anode A_2, A, A_1 negative with respect to the filament F_2, F, F_1. Therefore the P.D. between G and A_1 is $e + E$, G being positive with respect to A_1. The current i_2 through the condenser C_{ga} is therefore given by

$$i_2 = j\,(E + e)\,C_{ga}\omega \quad .. \quad (2)$$

and the total grid current is thus

$$i_g = i_1 + i_2 = j\omega[eC_{fg} + (E + e)\,C_{ga}]$$
$$= je\omega\left[C_{fg} + C_{ga} + \frac{E}{e}C_{ga}\right] \quad (3)$$

The input admittance of the valve is therefore given by

$$A_g = j\omega\left[C_{fg} + C_{ga} + \frac{E}{e}C_{ga}\right]$$

or $$A_g = j\omega[C_{fg} + C_{ga} + kC_{ga}] \quad .. \quad (4)$$

The actual amplification k produced by the valve must be regarded as a vector, since the two P.D.s e and E are not necessarily in phase. At low frequencies (the audio range, say), when the admittances of the valve capacities are small compared with that of the main anode circuit, A, F, F_2, A_2, the currents through these capacities will be very small compared with the anode current I, and as a first approximation we may write

$$I = \mu e/(R_a + Z).$$

$$\therefore \quad k = E/e = IZ/e = \mu Z/(R_a + Z) \quad .. \quad (5)$$

and $$A_g = j\omega[C_{fg} + C_{ga} + \mu ZC_{ga}/(R_a + Z)] \quad .. \quad (6)$$

When the load in the anode circuit is a pure resistance R, as in the resistance amplifier, this becomes

$$A_g = j\omega[C_{fg} + C_{ga} + \mu RC_{ga}/(R + R_a)] \quad .. (7)$$

In this case the input admittance is purely capacitative, the effective value of the capacity being $C_{fg} + C_{ga} + \mu RC_{ga}/(R+R_a)$. When the impedance added in the anode circuit possesses a reactance component, the input admittance will be found to contain a conductance component, which is positive when the reactance is negative (capacitative) and negative when the reactance is positive (inductive). A more detailed mathematical investigation of these points is given in my Physical Society* paper previously referred to, but the above is sufficient to show that the grid current of a valve is usually much greater than that passing through the grid-filament capacity, its actual value being greater, the greater the value of the actual voltage amplification obtained. This increase of grid current is due to the current carried by the grid-anode capacity, and can only be kept small by making this capacity as small as possible. On the input side, a valve with a resistance R in the anode circuit can be regarded as a condenser of capacity $C_{fg} + C_{ga} + kC_{ga}$, where k is the actual voltage amplification given by the valve. Thus, if a high voltage factor valve gives an actual amplification of 20 per stage, and the inter-electrode capacities are each 5 $\mu\mu$F., the effective grid capacity is 110 $\mu\mu$F., and if this is the second valve in Fig. 3, the grid leak R_1 must be regarded as shunted not merely by 5 $\mu\mu$F. but by 110 $\mu\mu$F.

The above results have been deduced on the assumption that the network shown in Fig. 2 is exactly equivalent to a valve. Some workers have found difficulty in accepting this diagram. It must be regarded as being to some extent empirical. The justification for its use lies in the fact that if the general equations of the network are written down, and then compared with the most generalised form of the equations† for small changes in the currents and voltages in a three-electrode valve network, the two are found to be identical, if the following relations are satisfied :—

(1) The thermionic current I between filament and anode is a function of the single variable $(V + \mu v + c)$, where V is the anode-filament P.D., v the grid-filament P.D., μ the voltage factor of the valve, and c a constant (which may be zero) depending on the construction of the valve, *i.e.*,

$$I = F\,(V + \mu v + c).$$

Also $$\frac{\delta I}{\delta V} = \frac{1}{R_a}$$

(2) The thermionic current i between filament and grid is practically zero and is unaffected by small changes in anode

---

* *Proc. Phys. Soc.*, Vol. 39, p. 108, 1927.

† Nichols, *Phys. Rev.*, Vol. 13, p. 411, 1919.

potential or grid potential, *i.e.*,

$$\frac{\delta i}{\delta V} = 0 \text{ and } \frac{\delta i}{\delta v} = 0.$$

These relations can be verified experimentally for a valve, used under the conditions which exist in amplifiers, *i.e.*, with sufficient negative grid bias to keep the grid current zero.

The author has made direct measurements of input admittance, and since the results were found to satisfy equations (6) and (7), these measurements may also be regarded as establishing the validity of the network given.

The Direct Measurement of Input Admittance.

The circuit used for measuring input admittance is shown in Fig. 4. It will be seen to consist essentially of a simple four-arm bridge for the measurement of capacity and conductance. The ratio arms R_3 and R_4 are equal non-inductive resistances of, say, 1,000 or 5,000 ohms each. C_1 is a standard variable air condenser reading up to 0.001 μF. C_2 may be a fixed condenser of this amount, and C_4 is a variable air condenser of 0.001 μF. Alternating current of telephonic frequency is applied between the points *A* and *D*. The balance detector *T*, connected to the points *F* and *B*, consists of a two-stage amplifier and telephone receiver. The grid circuit of the valve under test is connected in parallel with the condenser C_1 as shown. The grid bias battery *GB* is in series with the valve oscillator supplying the alternating current, and it is to be noted that this maintains the grid *G* at any desired static potential with respect to the filament *F*.

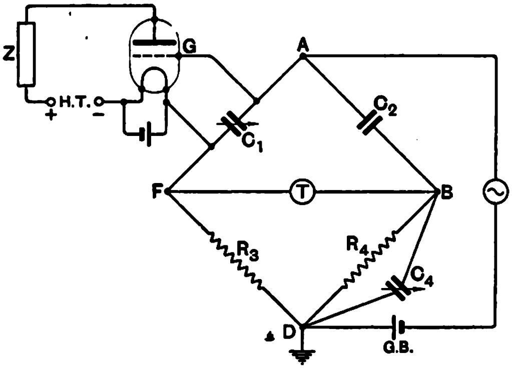


Fig. 4.—*Bridge for input impedance measurement.*

The measurement is made as follows: The circuit being completed as shown, the condensers C_1 and C_4 are varied until the bridge is balanced, and the telephone detector is silent. The readings of C_1 and C_4 are noted. The grid of the valve is then disconnected from the bridge at the point *G*, and balance again obtained by adjusting the values of C_1 and C_4. Let C_1' and C_4' be the new values, then we have

$$\text{Input capacity} = C_1' - C_1 \quad \ldots \quad \ldots \quad (8)$$

$$\text{Input conductance} = \omega^2(C_4 - C_4')R_4^2C_2/R_3 \quad \ldots \quad (9)$$

This may be proved as follows: When the bridge is balanced, there is no current in *FB*, and therefore the current through R_3 is equal to that flowing from *F* to *A*, *i.e.*, in the usual notation $i_g + jv_gC_1\omega$. The current through the arms *DB* and *AB* will similarly be equal. Denote it by i_2. Then equating the potential differences in the arms *DF* and *DB*,

$$(i_g + jv_gC_1\omega)R_3 = i_2\Big/\left(\frac{1}{R_4} + j\omega C_4\right)$$

Similarly, for the arms *FA* and *BA*

$$v_g = i_2/j\omega C_2$$

Dividing the first of these equations by the second, we have

$$\left(\frac{i_g}{v_g} + j\omega C_1\right) R_3 = j\omega C_2/(1/R_4 + j\omega C_4) \quad \ldots (10)$$

When the valve is disconnected from the bridge at *G*, the current i_g no longer flows from *F* to *A*, and C_1' being the new reading of the condenser C_1, the equation of balance becomes

$$j\omega C_1'R_3 = j\omega C_2/(1/R_4 + j\omega C'_4) \quad \ldots \quad (11)$$

Subtracting (10) and (11)

$$\left[\frac{i_g}{v_g} + j\omega(C_1 - C_1')\right]R_3 = j\omega C_2\left[\frac{j\omega(C_4' - C_4)}{\left(\frac{1}{R_4} + j\omega C_4\right)\left(\frac{1}{R_4} + j\omega C_4'\right)}\right].$$

In practice ωC_4 is small compared with $1/R_4$. We therefore obtain the working equation

$$\frac{i_g}{v_g} = j\omega(C_1' - C_1) + \omega^2C_2(C_4 - C_4')R_4^2/R_3$$

which is equivalent to the equations (8) and (9) given above. In a bridge of this nature the most probable sources of error are the earth capacities of the various batteries, but if the measurement is carried out exactly as described above, these are eliminated. The point D of the bridge being earth connected, the earth capacities of the H.T. and filament batteries may be regarded as a capacity shunt across the resistance R_3. This is balanced by the condenser C_4, and as the valve is disconnected at the point G only, these earth capacities are present when both balances are being obtained. They could be represented by constant terms added to equations (10) and (11), but on taking the difference they cancel out so that the working equation remains correct in spite of such capacities. The valve circuit was mounted on a board which was insulated by paraffin wax blocks, and batteries of small bulk were used, so that the earth capacities were as small as possible, but measurements can be successfully made even when these conditions are less satisfactory. The battery providing the grid bias lies entirely outside the bridge proper, and therefore has no undesirable effect on readings at the balance point.

The input P.D. used for the measurement was of the order of 0.1 volt.

Typical Values of Input Capacity and Conductance.

The values of the input capacities and conductances of a series of typical valves with various resistance loads in the anode circuit were determined by the method described above. The values of input capacity are given in Table I, and those of conductance in Table II. In the case of valve R.C.2, the observations were made at a frequency of 2,000 cycles; in the other cases the frequency was 1,000 cycles. In the tables, R is the resistance added in the anode circuit of the valve. Throughout each series of measurements the H.T. battery voltage was kept constant; the actual P.D. between filament and anode varied therefore when the resistance load in the anode circuit was changed. The actual values of the H.T. battery voltage, filament voltage, and grid bias, together with other data for the various valves are given in Table III.

TABLE I.

VALUES OF INPUT CAPACITY FOR VARIOUS VALVES.

R	Input Capacity for Valve.			
	P.M.1 H.F.	S.P.18.	R.C.2.	P.M.5B.
Ohms.	μμF.	μμF.	μμF.	μμF.
0	12	9	8	13
10,000	54	58	—	69
20,000	81	83	—	103
50,000	124	118	67	171
100,000	165	139	82	231
200,000	—	—	164	1,257
570,000	202	179	298	2,450
1,000,000	—	—	330	2,570
4,300,000	220	173	363	2,730
6,000,000	218	171	358	—

TABLE II.

VALUES OF INPUT CONDUCTANCE FOR VARIOUS VALVES.

R	Input Conductance for Valve.			
	P.M.1 H.F. at 1,000.	S.P.18 at 1,000.	R.C.2 at 2,000.	P.M.5B at 1,000.
Ohms.	μ mho.	μ mho.	μ mho.	μ mho.
0	0.004	0.002	0.006	0.004
10,000	0.015	0.026	—	0.020
20,000	0.027	0.041	—	0.037
50,000	0.045	0.061	0.11	0.079
100,000	0.060	0.065	0.13	0.137
200,000	—	—	0.33	1.06
570,000	0.12	0.098	0.67	2.21
1,000,000	—	—	0.89	2.71
4,300,000	0.23	0.14	1.7	4.92
6,000,000	0.26	0.16	1.9	—

Both the internal resistance R_a of the valve, and the voltage factor μ were actually measured under the conditions of use. In the cases of valves P.M.1 H.F. and S.P.18 the negative grid bias used might have been smaller with advantage, but in the other two cases the best value of the grid bias was found by trial, and this value was then used in making the measurements. The rated filament voltage of the valve P.M.5B was higher than 4 volts, but in practice the valve was found to be less effective when the filament voltage was increased.

The general trend of the results given in Tables I and II is such as may be expected from the theoretical discussion given above *i.e.*, as the resistance load in the anode circuit is increased, the input capacity becomes larger in accordance with equation (7). When the anode resistance is 1 megohm, the input capacity is several hundreds of micro-microfarads, the higher values being associated with valves of high voltage factor. The input conductance increases in a similar manner. The agreement between measured values and theory is not, however, strictly quantitative. Thus when $R = 0$ the input capacity is by equation (7) equal to $C_{fg}+C_{ga}$, and when R is very large the input capacity gradually approximates to $C_{fg} + C_{ga} + \mu C_{ga}$. Thus the difference between the initial and final values should give the value of μC_{ga}, and knowing the value of μ, the value of C_{ga} should be calculable. The values of C_{ga} calculated from the results in Tables I and III are given in Table IV.

Comparing these results for C_{ga} with the values of the input capacity when $R = 0$, we notice that the calculated values are all larger than is to be expected. In the case of the valve P.M.5B the difference is very large. The values of input capacity for this valve reached the enormous value of 2,730 $\mu\mu$F. The author cannot at present offer any complete explanation of this. It may be that this particular valve is not typical of its class, but no other sample was available at the time these measurements were made, so that this point could not be investigated. In any case, the fact that such very high values of input capacity can be met with is of obvious practical importance.

TABLE III.

FUNDAMENTAL CONSTANTS OF THE VALVES.

Valves.	Filament Voltage.	Anode Voltage.	Grid Bias.	R_a.	μ.
P.M.1 H.F.	2.0	60	−2.0	57,500	12
S.P.18	2.0	60	−2.0	27,000	8.5
R.C.2	2.0	100	−1.0	338,000	45
P.M.5B ...	4.0	150	0	57,100	34

The values of the input conductance given in Table II corresponding to high values of anode resistance are also larger than is to be expected from formulæ derived from the equivalent circuit for a valve given in Fig. 2, assuming that the constants of this circuit are those measured by the usual methods. These deviations from the formulæ are, however, mainly of theoretical interest. Generally speaking, the results can be expressed with all the accuracy required in practice, by the formulæ given. As for the deviations, it is sufficient to remember that in using the formulæ, the input capacity and conductance are more likely to be under-estimated than over-estimated.

TABLE IV.

CALCULATED VALUES OF GRID-ANODE CAPACITIES.

Valve.	μC_{ga}.	μ.	C_{ga}.
	$\mu\mu$F.		$\mu\mu$F.
P.M.1 H.F.	207	12	17
S.P.18	163	8.5	19
R.C.2	350	45	7.8
P.M.5B	2,720	34	80

The input conductance is apt to vary greatly with the frequency, but as it is usually of very little importance compared with the input capacity, this point will not be considered in detail. The input capacity was found to decrease as the frequency increased, but the change is not very great, *e.g.*, the capacity decreased by 15 per cent. when the frequency increased from 1,000 ∼ to 4,000 ∼. This is almost certainly due to the fact that the inter-electrode capacities decrease by about this amount with increase of frequency. In studying the effect of input capacity in low frequency amplifiers, this change of capacity with frequency may be safely ignored, as being a second order effect.

Application to the Resistance-capacity Amplifier.

It has been shown that for the purposes of analysis two stages of a resistance amplifier should be represented by the diagram shown in Fig. 3. Let us now confine our attention to the amplification produced by any one stage, that is to say, we wish to find the relation between the P.D. (e) applied to the grid-filament of this stage, and the P.D. (E) transferred to the grid-filament of the next valve. E is evidently the P.D. across the grid leak R_1 (Fig. 3). Now we have just shown that the effect of the second valve on R_1 is merely to shunt it by its "input admittance" which is equivalent to a capacity C_g (of the order of several hundreds of micro-microfarads) in parallel with a conductance, which is likely to be at least of the order 0.1 μ mho (equivalent to a shunt of 10 megohms) at 1,000 cycles, and larger at higher frequencies. Thus when considering only the amplification produced by the first stage, we may simplify the diagram to that shown in Fig. 5. Here the leaky condenser $G_g + jC_g\omega$ represents the second valve. The filament-anode capacity of the first valve merely acts as a shunt across the anode resistance R, as may be seen from Fig. 3; it is therefore transferred to this resistance in Fig. 5, where Z denotes the impedance of this resistance with its capacity shunt. Let Z_g denote the input impedance of the second valve with its grid leak, *i.e.*, Z_g is the resultant of the resistance R_1 in parallel with the admittance $G_g + jC_g\omega$. Let also the various mesh currents be as shown in Fig. 5. The equation for the mesh $APQF$ is

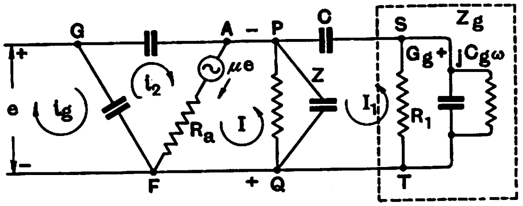


Fig. 5.—*Simplified equivalent network for two-stage amplifier.*

$$\mu e = I(R_a + Z) - I_1 Z + R_a i_2 \quad .. \quad (12)$$

For the mesh $PSTQ$ we have

$$0 = I_1(Z + Z_c + Z_g) - IZ \quad .. \quad (13)$$

where Z_c denotes the impedance of the condenser C.

$$\text{Also} \qquad E = I_1 Z_g \quad .. \quad .. \quad (14)$$

and, as was shown in a previous paragraph,

$$i_2 = j(E + e)C_{ga}\omega \quad .. \quad (2)$$

Eliminating I and i_2 from equations (12), (13) and (2) we have

$$\mu e - j(E + e)C_{ga}\omega R_a = I_1\left[\frac{(Z + Z_c + Z_g)\,(R_a + Z)}{Z}\right] - Z \quad (15)$$

Now eliminating I_1 from (14) and (15) and denoting the actual magnification of voltage E/e by k we find

$$k = \frac{E}{e} = \frac{\mu - jR_aC_{ga}\omega}{\left\{\frac{(Z + Z_c + Z_g)(R_a + Z) - Z^2}{ZZ_g}\right\} + jR_aC_{ga}\omega} \quad .. \quad .. \quad (16)$$

This may be written in the form

$$k = \frac{\mu BD\left(1 - j\frac{A}{\mu}\right)}{(1 + jABD)} \quad .. \quad (17)$$

where
$$A = R_aC_{ga}\omega$$
$$B = Z/(Z + R_a)$$
$$D = Z_g\Big/\left(Z_g + Z_c + \frac{ZR_a}{Z + R_a}\right)$$

Thus the expression for the actual voltage magnification (k) may be regarded as consisting of the voltage factor (μ) of the valve, multiplied by three modifying factors, viz., the anode impedance term B, the coupling term D, and the remaining term

$$(1 - jA/\mu)/(1 + jABD)$$

which represents the effect of the grid-anode capacity of the valve. Consider now the effect of these factors on the performance of the amplifier.

(a) The Grid-anode Capacity Effect.

It is evident that in a well-designed amplifier the coupling terms B and D will approximate to unity, being actually somewhat less than this. The magnitude of the quantity A was determined for a number of valves, the values for a typical audio-frequency being given in Table V.

TABLE V.

VALUES OF THE REACTION FACTOR A.

Valve.	R_a.	C_{ga}.	ω.	$A = R_aC_{ga}\omega$
	Ohms.	$\mu\mu$F.		
P.M.1 H.F.	57,500	4.5	10,000	0.00256
S.P 18G...	27,000	2.9	10,000	0.00078
R.C.2	338,000	2.2	10,000	0.0074
P.M.5B ...	57,100	5.3	10,000	0.0030

The values of grid-anode capacity given in this table were determined by a method previously described,* the valve being mounted in its holder (a commercial valve holder of low capacity), and the filament being cold. The values of input impedance previously given suggest that the effective value of the grid-anode capacity when the valve is operating under certain conditions, may be appreciably larger than this. The values given in Table V must, therefore, be regarded as minimum values. Values of A are given for a typical audio frequency ($\omega = 10{,}000$ or 1,600 cycles). It will be seen that for all audio frequencies the value of A is always small compared with unity.

---

* *E.W. & W.E.*, Vol. 2, p. 263. Feb., 1925.

Now since the terms B and D approximate to unity, the grid-anode capacity term approximates to $\left(1 - j\frac{A}{\mu}\right)/(1+jA)$, and bearing in mind that A is small compared with unity at audio frequencies, it is easy to see that this expression has an amplitude which is given approximately by $1 - \frac{1}{2}A^2\left(1 - \frac{1}{\mu^2}\right)$, or still more simply $1 - \frac{1}{2}A^2$. Thus the reaction effect of the grid-anode capacity causes a reduction of voltage amplitude, which expressed as a percentage has a maximum value of $A^2/200$. It is evident from Table V that this will be negligible in all practical cases of audio frequency amplification. This reduction of amplitude is associated with a change of phase, which, since A is small compared with unity, is given approximately by

$$\tan\phi = -\frac{\mu + 1}{\mu}A$$

where ϕ represents the rotation of the output voltage vector due to grid-anode capacity coupling. Thus both the change of phase and the reduction of amplitude are very small in all practical cases of L.F. amplification. The effect is larger the higher the anode circuit resistance of the valve. As an extreme case, consider a valve with an anode circuit resistance of 500,000 ohms, and let the grid-anode capacity be 4.5 $\mu\mu$F. It will be found that the reduction of amplitude due to this cause is 1 per cent. at 10,000 cycles, and the change of phase is about 8 degrees. The change of phase is, of course, proportional to the frequency, and the reduction of amplitude to the square of the frequency.

(b) The Anode Impedance Term

$$Z/(Z + R_a).$$

This term allows for the reduction of amplitude due to the internal resistance of the valve. In order that this reduction may be small, the added anode impedance Z should be large compared with the valve resistance R_a. If this condition is satisfied, there will also be no distortion due to this term, even when the impedance Z is not a pure resistance, since Z appears in both the numerator and denominator of the above term and thus, provided R_a is small compared with Z, any frequency changes in Z cancel out.

(c) The Coupling Term

$$Z_g/[Z_g + Z_c + ZR_a/(Z + R_a)].$$

This term represents the effect of the coupling condenser C and the grid leak, and input impedance of the next valve. Now since the impedance Z_c is inversely proportional to the frequency, this will cause distortion unless it is small compared with Z_g even at the lowest frequency. This condition is easily satisfied by making C large. Mr. Colebrook has discussed this point, and what he has said is entirely unaffected by the discussion in this paper. His value of 0.001 $\mu\mu$F. or 0.002 μF. may therefore be taken as a good practical case, and the term Z_c may be omitted from further consideration. The coupling term now reduces to $Z_g/[Z_g + ZR_a/(Z + R_a)]$. From this it is evident that, in order to get a large amplification, the resultant grid circuit impedance Z_g must be large compared with $ZR_a/(Z + R_a)$ which is the impedance of R_a and Z in parallel. Now we have seen that Z should be large compared with R_a, in which case $ZR_a/(Z + R_a)$ becomes simply R_a, and the coupling term reduces to $Z_g/(Z_g + R_a)$. The condition for maximum amplification is therefore that Z_g must be large compared with R_a. If this condition can be satisfied it does not matter what the phase angle of Z_g is, since it appears in both numerator and denominator, and thus frequency changes cancel out as long as R_a is small compared with Z_g.

In making a quantitative study of these effects it is convenient to work in terms of admittances and conductances, rather than impedances and resistances. Thus putting $G_a = 1/R_a$:

$$1/Z = A_x = G_x + jC_x\omega,$$

$$1/Z_g = A_g = 1/R_1 + G_g + jC_g\omega \text{ (see Fig. 5)}$$

$$= G_1 + G_g + jC_g\omega.$$

Then neglecting Z_e, the coupling term may be written

$$D = \frac{A_x + G_a}{A_x + G_a + A_g}$$

The anode impedance term becomes

$$B = \frac{G_a}{A_x + G_a}$$

Thus the product of these becomes

$$BD = \frac{G_a}{G_a + A_x + A_g}$$

whence, neglecting the grid-anode capacity effect,

$$k = \mu BD$$

$$= \frac{\mu G_a}{G_a + G_x + G_1 + G_g + j\omega C_x + j\omega C_g} \quad (18)$$

which expresses in a very simple manner the reduction of voltage amplitude due to the anode circuit added resistance ($1/G_x$), the grid leak ($1/G_1$), and the input conductance of the following valve (G_g); and also the reduction of amplitude and change of phase due to the capacity C_x associated with the load in the anode circuit (this includes the filament-anode capacity of the valve) and the input capacity C_g of the following valve. The design of a L.F. amplifier should be such that all these reductions in amplitude are kept small, and when this is the case the actual fractional reduction of amplitude is given by:

Fractional decrease in voltage amplitude

$$= \frac{G_x}{G_a} + \frac{G_1 + G_g}{G_a} + \frac{1}{2}\left(\frac{C_x^2\omega^2}{G_a^2} + \frac{C_g^2\omega}{G_a^2}\right) \quad .. \quad (19)$$

and the change of phase is an angle ($-\theta$) given by

$$\tan\theta = \frac{(C_g + C_x)\omega}{G_a + G_x + G_1 + G_g}$$

$$\div \frac{C_g\omega}{G_a} = R_aC_g\omega \quad .. \qquad .. \quad (20)$$

These expressions show that the effects of the various components of the amplifier, on the voltage amplification produced by any one stage, are as follows:—

(1) The anode circuit resistance. This causes a reduction of voltage amplitude, which expressed as a fraction is given by R_a/R_x.

(2) The filament-anode capacity of the valve causes a fractional reduction of voltage of $\frac{1}{2}R_a^2C_{fa}^2\omega^2$, and a change of phase of approximately $R_aC_{fa}\omega$ radians. If the load in the anode circuit possesses an appreciable reactance, this may be regarded as modifying the value of C_{fa} giving a resultant value C_x.

(3) The grid leak of the following valve causes a fractional reduction of voltage amplitude given by R_a/R_1.

(4) The Input Conductance of the following valve causes a fractional reduction of voltage of G_g/G_a.

(5) The Input Capacity of the following valve causes a fractional reduction of voltage amplitude of $\frac{1}{2}R_a^2C_g^2\omega^2$, and a change of phase of approximately $R_aC_g\omega$ radians.

The change of phase is of no great consequence, but the reduction of voltage may be serious. The reduction of voltage due to the grid leak R_1 and the resistance added in the anode circuit R_x, is independent of the frequency, and therefore causes no distortion. The input conductance G_g of the following valve may vary greatly with the frequency, and unless it is small compared with $1/R_a$, there will be distortion in addition to a reduction of amplitude. For a valve of high voltage factor G_a may be no more than 4μ mhos and since G_g may be as large as 0.5μ mho (see Table II) this effect may be quite serious. Table II shows that the input conductance of a valve increases rapidly when the resistance in its anode circuit becomes very great. Thus the practice of using very high anode resistances in any stage of an amplifier may have this undesirable effect. The reduction of voltage amplification in that particular stage due to this resistance is certainly made small, but the input conductance of the valve is increased, and the voltage amplification produced by the preceding stage is thereby decreased, and a certain amount of distortion is introduced.

The effects of filament-anode capacity, reactance in the anode circuit load, and the input capacity of the following valve, are of exactly the same nature. Table I shows that the input capacity of any ordinary valve is likely to be between 100 and 200 $\mu\mu$F. The filament anode capacity may be neglected in comparison, or we may combine the two and consider the resultant capacity.

The fractional reduction of voltage amplitude due to this capacity is approximately given by $\frac{1}{2}R_a^2C_g^2\omega^2$. Take the case of a valve like the P.M.1 H.F. for which $R_a = 57{,}000$ ohms. C_g will be at least 100 $\mu\mu$F. and it will be found that the fractional reduction of voltage amplitude in such a case is about 4 per cent. at 8,000 cycles and 0.04 per cent. at 800 cycles. In the case of a high voltage factor valve, R_a is much greater and the loss of voltage amplitude becomes so great that the above approximate expression no longer holds. A more accurate expression which can be used in such cases is obtained from equation (18), from which it will be seen that the magnitude of the voltage amplification is

$$\frac{\mu}{\sqrt{\left(1 + \frac{G_x}{G_a} + \frac{G_g}{G_a}\right)^2 + R_a^2C_g^2\omega^2}}$$

$$= \frac{\mu}{\sqrt{\left(1 + \frac{R_a}{R_x} + G_gR_a\right)^2 + R_a^2C_g^2\omega^2}}$$

It is a convenience in calculation to denote $R_aC_g\omega$ by $\tan\theta$ (equation 20). Then the above expression is approximately

$$\mu \cos\theta\left(1 - \frac{R_a}{R_x} - R_aG_g\right)$$

since the terms R_a/R_x and R_aG_g are small. Thus the effect of the input capacity C_g is given by the factor $\cos\theta$. Values of these effects for certain cases are given in Table VI. Two typical valves are taken, and assuming a value of 100 $\mu\mu$F. for the input capacity of the following valve, the effect of this on the amplification is calculated for values of ω up to 50,000 (8,000 cycles per sec.). The value of $R_aC_g\omega$ gives $\tan\theta$, from which the change of phase θ, and the amplification factor $\cos\theta$, are immediately obtained. The last column gives the percentage reduction of voltage due to the input capacity of 100 $\mu\mu$F. It will be seen from Table I that the actual input capacity may be very considerably greater than this, and the effects may therefore be even larger than those given in Table VI. In the case of the valve with 300,000 ohms anode circuit resistance, the reduction of voltage is nearly 50 per cent. at 8,000 cycles, and 1.4 per cent. at 800 cycles. The 50,000 ohm valve shows a voltage reduction of only 3.9 per cent. at 8,000 cycles. It is evident that if a valve of high internal resistance is used in a resistance-capacity amplifier, considerable distortion must result, unless the effect of the input capacity of the following valve can be corrected in some way.

TABLE VI.

EFFECT OF AN INPUT CAPACITY OF 100 $\mu\mu$F. ON VOLTAGE AMPLIFICATION.

Valve.	ω.	$R_aC_g\omega$.	Change of Phase θ.	$\cos\theta$.	Reduction of Voltage — per cent.
P.M.1 H.F.	5,000	0.0287	1° 39′	0.9996	0.04
$R_a = 57{,}500$ ohms	10,000	0.0574	3° 17′	0.9984	0.16
$G_a = 17.4$ μ mho	20,000	0.115	6° 34′	0.9934	0.66
	40,000	0.230	12° 57′	0.9746	2.54
	50,000	0.287	16° 1′	0.9612	3.88
R.C.2	5,000	0.170	9° 39′	0.9859	1.4
$R_a = 338{,}000$ ohms	10,000	0.338	18° 41′	0.9473	5.3
$G_a = 2.95$ μ mho	20,000	0.676	34° 4′	0.8284	17.2
	40,000	1.35	53° 28′	0.595	40.5
	50,000	1.70	59° 32′	0.507	49.3

The Compensation of Input Capacity.

Probably the simplest way of making this correction is to use in the anode circuit of the valve, not a pure resistance load, but an inductive one.

Let L_x be the inductance of the anode circuit load and R_x be its resistance. The admittance A_x is given by $1/(R_x + jL_x\omega)$, and if $L_x\omega/R_x$ is so small that its square may be neglected in comparison with unity, this becomes $\frac{1}{R_x} - j\frac{L_x\omega}{R_x^2}$. The factor BD now becomes

$$BD = \frac{G_a}{G_a + 1/R_x + G_1 + G_g - j\frac{L_x}{R_x^2}\omega + jC_g\omega + jC_x\omega} \quad \ldots \quad (21)$$

If now the inductance L_x is such as to satisfy the condition

$$C_g + C_x = L_x/R_x^2 \quad \ldots \quad (22)$$

then it is evident that all the terms in involving frequency in the above expression for BD vanish, and therefore the inductance will compensate for both the change of phase and reduction of amplitude due to the capacities C_g and C_x. This compensation will hold for all frequencies for which $L_x^2\omega^2/R_x^2$ is negligibly small. Hence by (22) $R_x^2(C_g + C_x)^2\omega^2$ must be negligibly small, say $= 0.01$. Suppose the capacity to be compensated $(C_g + C_x)$ is 100 $\mu\mu$F., and that this is required to hold up to a frequency of 8,000 cycles $(\omega = 5 \times 10^4)$. Then we must have $R_x \times 10^{-10} \times 5 \times 10^4 \leqq 0.1$, *i.e.*, $R_x \leqq 20{,}000$ ohms. If the anode resistance is greater than this amount, the compensation will be less perfect at the upper frequencies, but in all cases there will be a definite reduction of distortion due to inter-electrode capacities if an inductive anode resistance is used.

In order to obtain some idea of the performance of typical anode resistances, a number of these were tested for self-inductance. Those of the type in which a metal film is contained in an evacuated glass tube were found to be very nearly pure resistances. Actually each one tested was found to have a self-capacity of about 0.2 $\mu\mu$F., which is accounted for by the capacity of the metal caps at the ends of the tube. This self-capacity was the same for all values of the resistance tested. Interesting results were obtained for the wire-wound anode resistances. The values, which were obtained at a frequency of 1,000 cycles, are shown in Table VII.

TABLE VII.

SELF-CAPACITY VALUES FOR WIRE-WOUND ANODE RESISTANCES.

Resistance.	Type.	Effective Self-capacity.
Ohms.		$\mu\mu$F.
20,000	Standard	− 30
50,000	,,	0
80,000	,,	+ 60
100,000	,,	+ 50
200,000	Bi-duplex	+ 8
500,000	,,	+200

It seemed probable at first sight that resistances of this type would be inductive, but actually the capacity effect was found to predominate for all resistances greater than 50,000 ohms. The 20,000 ohm resistance alone was found to be inductive. In this case the inductance is expressed as an equivalent negative capacity $(= - L_x/R_x^2)$. The inductance present would evidently compensate at audio frequencies an input capacity of this amount. It is to be noted that the resistances of higher values may have very considerable self-capacities. This is doubtless due to the fact that they are made of such small bulk. The " bi-duplex " type of winding evidently possesses advantages, but even this is not good for 500,000 ohms. It is important to realise that the reduction of amplitude due to input capacity may be doubled by the self-capacity of an anode resistance. If distortionless amplification is desired, it is evident that anode resistances must be kept low, which means that valves of high resistance are not desirable; also, if the anode resistances are not already inductive they should be made so by adding suitable copper wound inductance coils in series with them.

Conclusions.

From this discussion we see that if a low-frequency resistance amplifier is required to give distortionless amplification the components should satisfy the following conditions :—

(1) The condenser coupling the anode circuit of one valve to the grid of the next should be of large capacity, say, 0.002 μF. or greater. It must also have high insulation resistance.

(2) The valves used should not have a high internal resistance, R_a, since :

(*a*) The loss of amplification at the higher frequencies due to inter-electrode capacities is proportional to the square of this quantity.

(*b*) High resistance valves require high anode resistances in order to avoid a large reduction of output voltage. The use of high anode resistances possesses the disadvantages enumerated below (3).

(3) The anode resistances should be considerably larger than the internal resistances of the valves, but should not be of higher resistance than is necessary, and they should preferably be inductively wound, so as to compensate to some extent the input capacity of the following valve. Many wire-wound anode resistances of high value have large self-capacities, and should be used with discrimination. The metallic film in vacuum type is generally superior (from the point of view of distortion due to capacity reactance) for values greater than 50,000 ohms. The use of high anode resistances has also the following undesirable effects.

(*a*) The input conductance of the valve is increased, and as this may vary considerably with frequency, distortion will result.

(*b*) The internal resistance of the valve is increased unless the H.T. battery voltage is also increased. The increase in R_a means increased distortion as mentioned above (2).

This effect of increase in the resistance of the valve with increasing values of anode resistance is shown by the following results of measurements made on two valves (Table VIII). It will be seen from this that a valve of nominal resistance 10,000 ohms may have an actual resistance of 100,000 ohms or more, if it is used with a very high anode resistance, and the usual H.T. battery voltage.

(4) The resistance of the grid leak R_1 should be large compared with that of the preceding valve. It should not be of a type having large self-capacity, otherwise the input capacity effect of the next valve will be increased. As in the case of the anode resistance, an inductive winding will tend to diminish distortion due to inter-electrode capacity effects.

The general conclusion is that, although very high amplification per stage may be obtained by the use of valves of high voltage factor (and correspondingly high resistance) associated with high anode resistances, such amplification must be subject to considerable frequency distortion due to inter-electrode capacity effects. This distortion can only be avoided by using low resistance valves, in which case a lower amplification per stage will be obtained.

TABLE VIII.

THE INTERNAL RESISTANCES OF VALVES WITH VARIOUS ANODE RESISTANCES.

H.T. Battery voltage: 100 (maintained constant).
Grid Bias: – 2 volts.

Anode Resistance.	Internal Resistance of Valve.	
	D.E.R.	P.M.1 L.F.
1,000 ohms	18,800 ohms	9,560 ohms
20,000 ,,	23,600 ,,	13,000 ,,
100,000 ,,	33,100 ,,	20,450 ,,
500,000 ,,	66,000 ,,	44,000 ,,
2 megohms	130,000 ,,	100,000 ,,

The Heaviside Operator and the Operational Calculus.

By W. A. Barclay, M.A.

> "*I never use a big, big D!*"—H.M.S. PINAFORE.

MR. RATCLIFFE'S article on Symbolical Algebra (*E.W. & W.E.*, May, 1928) and Professor Howe's editorial on the same subject must doubtless have caused some heart searching among many wireless workers who are accustomed to use the symbol "j" without enquiring too closely into its meaning. The contributions in question, however, are contradictory, and cannot be said to approach that finality which we expect in scientific matters; they are statements of fundamentally opposite points of view regarding the meaning of j, whose use and functions appear to be as ill-defined as ever. Mr. Ratcliffe wishes it to mean $\sqrt{-1}$ on all occasions; Prof. Howe takes the more usual view that it has also an "operational" significance, and that there is a very great distinction between the two meanings. When honest men thus differ, a simple perversion of an old proverb would indicate that thieves are likely to come into their own. The writer accordingly makes no apology for taking advantage of this latest instance of the discord occasioned by the different interpretations of j to champion the cause of what is known as the "Heaviside Operator."

The j notation is, indeed, so universally established that there would be little point in attempting to supersede it in A.C. work were it not for the unfortunate cleavage of opinion in regard to its real meaning. Comparatively few people are acquainted with the Heaviside symbolism, which, as Prof. Howe has pointed out, involves merely a change of label without any change of fundamental ideas. In the following notes the writer will seek to prove his contention that of the two systems, the differential operator is the more fundamental, but in any case (and it is a big but) the Heaviside label has the advantage of admitting no possible misunderstanding. It should be remembered, too, that the extremely simple symbolism here described is only a very small portion of a vastly more general Operational Calculus which was devised by the fertile genius of Heaviside for wider fields of electrical work.

Symbolic Systems.

It is elementary knowledge that the bulk of the currents and voltages dealt with in wireless work are simple harmonic functions of a time variable, *i.e.*, they may be represented mathematically by functions of $\sin t$ and $\cos t$, where t represents time reckoned from some fixed zero. These sinusoidal functions are what are known as "steady-state" functions, and represent a condition of affairs which sets in after the transient initial variations have disappeared and the apparatus has settled down to the production of a steady alternating current. We thus deal throughout with variations similar to the C.W. system of transmission, where amplitude and frequency remain constant. Given such conditions, it is possible to devise several systems of mathematical "shorthand" which will materially lessen the labour of dealing with these functions.

In devising such a system of shorthand, care must always be taken to maintain a proper perspective, in order that any new symbols introduced may never be allowed to outrun their legitimate functions. Such undue liberty, unfortunately, has been accorded to the symbol j, which was introduced originally to amplify a geometrical interpretation of the variables $\sin t$ and $\cos t$. The conception of j as a vector operator is legitimate enough, but to make it stand, as Mr. Ratcliffe would have it do, for $\sqrt{-1}$ is to strain the meaning too far. A geometrical diagram is undoubtedly convenient to represent the circular functions, and geometrical statements may be used to illustrate their relations. But when we are asked to put these geometrical statements into algebraic form and reason about them "*without any thought as to the geometrical meaning of the symbols*," it will be realised that we have left our original electrical conceptions very far behind. To apply algebra to pure geometry is not at all the same thing as to apply it to the conceptions the geometry was originally intended to illustrate.

It is only natural, though from the point of view of logic a little unfortunate, that the sinusoidal variations of current and potential should lend themselves to such facile geometrical illustration as is afforded by the crank diagram. The use of circular functions leads immediately to talk of angles, phase difference as an angle, etc., conceptions which are highly convenient so long as recognised for what they are—polite fictions. The danger is that the crank diagram may become too geometrical a conception, and that algebra may be applied to this geometry *quâ* geometry.

The Heaviside Operator.

The Heaviside system completely ignores this extraneous and illustrative geometry. It confines itself strictly to the simplification of the algebra involved in the sine and cosine calculus which, as we have seen, is adequate to the steady state problems of A.C. work. The fundamental conception is the operation of time-differentiation, denoted by the symbol D, which thus stands for the operator $\frac{d}{dt}$. At the outset, therefore, the operator D is not to be treated as an algebraic quantity, but must be considered as operating on a function of the time. This operand may either be explicitly stated or implied. Thus, if

$$i = I \sin \omega t \quad .. \quad .. \quad (1)$$

represent the instantaneous value of a sinusoidal current at time t, its rate of increase at that instant will be written

$$Di = \frac{di}{dt} = \omega I \cos \omega t \quad .. \quad (2)$$

If we again operate on equation (2) with the operator D, we have

$$D\,(Di) = \frac{d^2 i}{dt^2} = -\,\omega^2 I \sin \omega t \quad .. \quad (3)$$

and by a suitable convention we may rewrite this as

$$D^2 i = -\,\omega^2 I \sin \omega t \,.. \quad .. \quad (4)$$

being careful to remember that the index attached to the D does not stand for algebraic multiplication, but for a repetition of the operation. Whenever the symbol D is used to operate on a simple harmonic function of time, we automatically suspend the working of pure algebra in connection with it, and translate the D into terms of $\frac{d}{dt}$ and hence of differentiation. Thus no confusion should ever arise regarding the nature of D. It is always an operator, and is recognised for such whenever we meet it. This cannot be said of the symbol j.

Since $\frac{d}{dt}\left[\int i\,dt\right]$ is defined as i, i.e., $D\int i\,dt = i$, we may regard the operation of time-integration as the inverse of time-differentiation, and write

$$\int i\,dt = \frac{i}{D} = D^{-1} i \text{ plus a constant.}$$

(When i is a sinusoidally varying current, this constant will be a non-oscillating or steady component which can be neglected in dealing with the reactions of a circuit to oscillatory currents.) If $i = I \sin \omega t$, we can thus write

$$D^{-1} i = \int i\,dt = -\frac{1}{\omega}\, I \cos \omega t \quad .. \quad (5)$$

The Operational Equation.

We have seen that,

$$D^2 \,.\, I \sin \omega t = -\,\omega^2 I \sin \omega t \quad .. \quad (6)$$

Also, by repeated differentiation it can be shown that

$$D^2 \,.\, I \cos \omega t = -\,\omega^2 I \cos \omega t \quad .. \quad (7)$$

Hence we see that, so long as the repeated operator D^2 is applied to a circular function of ωt, we may obtain the result of the operation by substituting $-\,\omega^2$ for D^2. We may express this fact by the operational pseudo-equation

$$D^2 = -\,\omega^2 \quad .. \quad .. \quad (8)$$

the nature of which we may pause to

consider. It is not an equation such as is commonly met with in algebra. The sign " = " does not here assert a numerical equality; the L.H.S. is purely an operator, the R.H.S. is an algebraic quantity. Equation (8) is really a disembodied equation, a sort of ghost. It is not, strictly speaking, an equation at all, and would be better left unwritten, since the meaning which we here give to the sign " = " must perforce differ from its usual connotation. What it implies is that we may always substitute $-\omega^2$ for D^2 whenever this occurs in an operator used in conjunction with a circular function of ωt. To establish fully the truth of this statement would take too long for our present purpose, but it is not difficult to show its truth in many simple instances. For example, if A be a numerical quantity, we may apply the operator $A^2 + D^2$ to the function $\frac{1}{A^2 - \omega^2} . \sin \omega t$. By actual differentiation, the result will be seen to be $\sin \omega t$. Hence, applying the inverse operator $\frac{1}{A^2 + D^2}$ to $\sin \omega t$, we obtain $\frac{1}{A^2 + D^2} . \sin \omega t = \frac{1}{A^2 - \omega^2} . \sin \omega t$ conformably to the above rule.

To regard (8) as in any sort an equation is a delusion which must be rigidly guarded against. In particular, we must beware of the fallacy of any attempt to derive an expression for D in terms of ω by " taking the square root of both sides " of (8) as is sometimes thought possible. D is not " equal to " $\sqrt{-1} . \omega$ any more than D^2 is " equal to " $-\omega^2$, and no such equality should be stated or even implied. D is defined as $\frac{d}{dt}$ and can mean nothing else. D^2 is defined as $\frac{d^2}{dt^2}$, and it is only by virtue of the special properties of the circular functions that we may write equation (8) as the symbolic form of equations (6) and (7).

The present article does not pretend to furnish a systematic account of the development of the D-symbolism and its uses. Readers may like to show for themselves that D obeys some but not all of the laws of algebra, in which respect it is analogous to the symbol j taken in its operational sense. The symbolism of the differential operator avoids all pictorial images, and by going directly to the root of the matter, gains much in simplicity and directness.

The Impedance Operator.

Let us now consider the circuit of Fig. 1 consisting of a resistance R, an inductance L, and a capacity C in series. If a current $i = I \sin \omega t$ flow through this, and e denote the instantaneous P.D. across the ends of the circuit at instant t, we have by Kirchhoff's Law,

$$e = R I \sin \omega t + L . \frac{d}{dt} I \sin \omega t + \frac{1}{C} \int I \sin \omega t . dt \quad .. \quad (9)$$

$$= \left(R + LD + \frac{1}{CD} \right) . I \sin \omega t$$

$$= \left(R + LD + \frac{1}{CD} \right) . i \quad .. \quad .. \quad (10)$$

To the symbols LD and $\frac{1}{CD}$ of equation (10) Heaviside gives the name of " resistance operators " in that they act upon i analogously to the resistance R, and may be used in symbolic algebra precisely as resistances. Thus, the P.D. across the terminals of the inductance L (through which $i = I \sin \omega t$ is passing) is obtained by applying the operator LD to the current in analogy with multiplication by R in the case of a resistance. We have then for the P.D. across the inductance

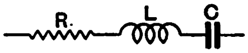


Fig. 1.

$$LD \, (I \sin \omega t) = L \omega I \cos \omega t \quad .. \quad (11)$$

Compound expressions such as that in brackets in equation (10) are known as " impedance operators," and may be written $\bar{Z}$, the bar denoting the operational character of the symbol. We may write, then,

$$e = \bar{Z} . i \quad .. \quad .. \quad (12)$$

which is a generalised expression for Ohm's Law applied to alternating currents in which $\bar{Z}$ is to be taken as an operator composed algebraically of ordinary circuital symbols and functions of D. *Considered by itself, this operator* $\overline{Z}$ *may be treated algebraically, and reduced by algebraic rules to its simplest form.* After this work is accomplished, it must be related to its operand, always a sinusoidal time function, so that the indicated differentiations may be performed. During the simplification of the operator $\overline{Z}$ we can treat D algebraically, and in the process we may replace D^2 by $-\omega^2$ wherever it occurs. This procedure is justified so long as the implicit operand is the sinusoidal time-function, and under these circumstances invariably leads to correct results.

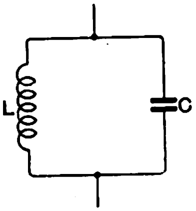


Fig. 2.

An Example.

The above considerations will be made clearer by an example. Let us take an inductance L and capacity C in parallel (see Fig. 2). Let $\overline{Z}$ denote the impedance operator for this combination. Then

$$\frac{1}{\overline{Z}} = \frac{1}{LD} + CD = \frac{1 + LCD^2}{LD}$$

Writing, as we may always do, $-\omega^2$ for D^2, we have

$$\overline{Z} = \frac{LD}{1 - LC\omega^2} \quad \ldots \quad \ldots (13)$$

Then, if the line current flowing past the system is $i = I \sin \omega t$, the P.D. e across the combination is

$$\begin{aligned} e &= \overline{Z} \, . \, i \\ &= \frac{LD \, . \, I \sin \omega t}{1 - LC\omega^2} \\ &= \frac{L\omega I \cos \omega t}{1 - LC\omega^2} \quad \ldots \quad \ldots (14) \end{aligned}$$

If, however, the E.M.F. across the system were given as $e = E \cos \omega t$, we should have for the line current

$$\begin{aligned} i &= e/\overline{Z} \\ &= \frac{(1 - LC\omega^2) \, . \, e}{LD} \end{aligned}$$

Rationalising the denominator,

$$\begin{aligned} i &= \frac{(1 - LC\omega^2)De}{LD^2} = \frac{(1 - LC\omega^2)D \, . \, E \cos \omega t}{-L\omega^2} \\ &= \left(\frac{1}{L\omega} - C\omega\right) . \, E \sin \omega t \quad \ldots \quad \ldots (15) \end{aligned}$$

Considerations of space forbid the detailed working out of the logical reasons on which this procedure is founded: those interested are recommended to study the treatment of the subject given by Dr. Eccles in his "*Continuous Wave Telegraphy.*" An important feature, and one to which the writer has previously called attention, is the entire absence of any reference to the imaginary unit.

Equation (13) is to be regarded as "symbolic" of equations (14) and (15), which latter are merely expansions of it to suit particular operands. It will be noted that a D is present in the numerator. This indicates that if the operand is a sine function of time the result will be a cosine function—as in equation (14). If, however, the D had not been present the nature of the operand would remain unaffected, the process being merely algebraical multiplication. In working with impedance operators our aim should always be to reduce them to the simple form

$$\overline{Z} = A + BD \quad \ldots \quad \ldots (16)$$

the second term of which alone effects a functional change in the operand which is implicitly understood.

Another Example.

As a further example of the use of the symbolism, take the common wireless circuit illustrated in Fig. 3. If $\overline{Z}$ be the operator impedance of the combination to line current,

$$\frac{1}{\overline{Z}} = \frac{1}{R + LD} + CD$$

Therefore

$$\begin{aligned} \overline{Z} &= \frac{R + LD}{1 + CD\,(R + LD)} \\ &= \frac{R + LD}{(1 - LC\omega^2) + CRD} \end{aligned}$$

This does not yet conform to the type of equation (16) as a D still occurs in the denominator. We must therefore multiply above and below by $(1 - LC\omega^2) - CRD$, obtaining

$$\overline{Z} = \frac{R + \{L(1 - LC\omega^2) - CR^2\} . D}{(1 - LC\omega^2)^2 + C^2R^2\omega^2}$$

Then, if the line current is given as $i = I \cos \omega t$, since $e = \overline{Z} . i$, we can write down for the voltage e across the combination

$$e = \frac{R}{(1 - LC\omega^2)^2 + C^2R^2\omega^2} . I \cos \omega t$$
$$- \frac{\omega L(1 - LC\omega^2) - CR^2\omega}{(1 - LC\omega^2)^2 + C^2R^2\omega^2} . I \sin \omega t \quad .. \quad (18)$$

In this equation, the first term preserves unchanged the original cosine function, while the second, being the result of the operation of differentiation, has been changed.

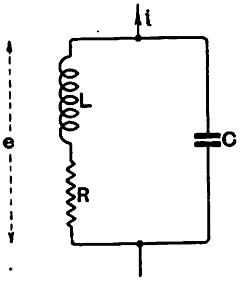


Fig. 3.

It will be evident that equation (16) is really the symbolic expression for an impedance in terms of its series resistive and reactive components. The ohmic value of the resistance is given by the term A; the term BD is the reactance operator, and the corresponding ohmic reactance is $B\omega$, obtained by simply replacing the D in the operator by ω. To prove this in the case of simple reactances, suppose we take first an inductance L. Here the operator is LD, which by the rule gives $L\omega$ for the ohmic reactance. Again, if we consider capacity, the operator is $\frac{1}{CD}$, which may be brought to form (16) by writing $\frac{D}{CD^2}$ or $\frac{-D}{C\omega^2}$. Replacing the D by ω, we have the correct capacitative reactance $-\frac{1}{C\omega}$.

Summary of Procedure.

We now briefly summarise the procedure connected with the Differential Operator as applied to A.C. problems.

First express the impedance of the circuit as an operator, using the resistance operators R, LD and $\frac{1}{CD}$ as though they were ordinary resistances, and manipulate the expression algebraically until it assumes the form

$$\overline{Z} = A + BD.$$

The ohmic resistance is then A, the ohmic reactance is $B\omega$. Whence, as usual, $\phi = \tan^{-1} \frac{B\omega}{A}$, and the numerical value of the impedance is $|Z| = \sqrt{A^2 + B^2\omega^2}$.

Applying the operator $\overline{Z}$ to its operand, a sinusoidal function of ωt, the D indicates a time-differentiation to be performed on that function. The symbolism is, therefore, applicable to R.M.S. and instantaneous values alike.

Criticism of the Differential Operator.

It will be admitted that the time rates of change of the currents and potentials met with in wireless work are not less important to the subject than are the varying values of the quantities themselves. Herein, it is claimed, lies the advantage of D over a vector operator which rotates an illustrative geometrical vector through 90°, and is liable to confusion with $\sqrt{-1}$! Indeed, the whole conception of a geometrical vector, indispensable though it undoubtedly is in electrical work, yet in strictness introduces additional complication into the subject, regarding the nature of which it is as well to be quite clear.

Two years ago in the correspondence columns of this journal, Prof. Howe called attention to a fact never in dispute, viz.: that D used in conjunction with its operand is not an algebraic quantity and cannot be treated as such. In his editorial of May, 1928, he returns to this charge, saying that I claimed an enormous simplification by using D/ω, but that he had shown the impossibility of using D/ω as an algebraic multiplier. Since, however, D/ω was never intended to be treated as an algebraic multiplier when used with a time operand, but can only *operate* on that operand, this cannot be regarded as a valid argument against D. When the operand is understood, *i.e.*, when we are working symbolically, we can treat D algebraically even though it is not an algebraic quantity; when, however, the operand is shown explicitly, we must remember that the function of D is to operate on it. The philosophy of the subject is abstruse, yet it may be defended on pragmatic grounds. It is, indeed, one of the leading recommendations of the Heaviside operator that we always know it for such whenever we meet it, and are on our guard against such unwarrantable algebraic treatment as Prof. Howe instances.

The Heaviside Operational Calculus.

The above necessarily brief sketch of the Heaviside operator in its application to alternating currents has taken no account of its wider employment in more recondite problems for the solution of which, indeed, it was first invented. The difficulties of the subject do not permit of even the slightest treatment here; nevertheless it is felt that in view of the gradually awakening interest in Heaviside and his methods by electrical engineers both in this country and abroad, some reference to the subject was desirable in *E.W. & W.E.*

As a mathematician Heaviside was mainly self-taught, and in consequence was accustomed to think out for himself new and unorthodox ways of tackling old problems. The chief operational method which he devised for the solution of the differential equations occurring in transmission-line and other problems depends upon the symbolic expression of the equations in terms of D. The equation being expanded algebraically in ascending inverse powers of D, Heaviside gives rules for replacing the operators by specified functions of the time variable, thus giving a power series solution of the differential equation. Another very powerful method of symbolic solution, stated by the inventor without proof, is known as the Heaviside "Expansion Theorem," and depends on the algebraic solution of the symbolic equation. These rules, as given in somewhat haphazard fashion in the pages of his treatise "*Electromagnetic Theory*," are subject to notable exceptions, and were for long regarded with much suspicion by his fellow scientists who were disinclined to follow the prolixities of the inventor's rather tedious style. Of recent years, however, the great simplicity attending Heaviside's use and interpretation of fractional powers of his operator has resulted in more attention being paid, especially in America, to this important subject. As a consequence the Heaviside Operational Calculus—originally the outcome of an almost extraordinary intuition—may now be said to be established on a sound mathematical basis. To those who have the necessary mathematical equipment, J. R. Carson's "*Electric Circuit Theory and the Operational Calculus*" (McGraw-Hill) may be commended as an advanced but very adequate exposition of a fascinating subject.

The Resonance Curves of Coupled Circuits.

By Prof. E. Mallett, D.Sc., M.I.E.E.

INTRODUCTION.

In a previous article[*] the resonance curves of single oscillatory circuits were obtained by vectorial methods, and it was shown how the simple resonance curves were modified by the inclusion of a valve in the circuit arrangement. It was found also that even if a second tuned circuit was coupled with the first the resonance curve obtained by varying the circuit condensers was still "simple," that is, it could be derived from a vector locus diagram consisting of straight lines and circles. It was, however, mentioned that the resonance curve in the case of coupled circuits obtained when the frequency is varied is no longer simple, but in one particular case is derived from a parabola. The purpose of this article is to follow up this treatment of the coupled circuit case with frequency varied, and to extend it to a chain of resonant circuits with three, four, or more links.

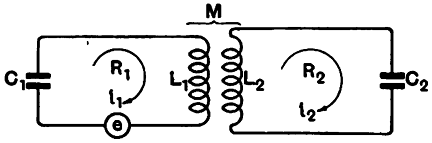


Fig. 1.

I. Two Tuned Circuits Coupled by Mutual Inductance.

Suppose that an electromotive force $e \cos \omega t$ is introduced into the first of two oscillatory circuits having inductance L_1, capacity C_1, and total resistance R_1, coupled by a mutual inductance M (as indicated in Fig. 1) with a second oscillatory circuit with corresponding constants L_2, C_2, R_2.

The steady currents i_1 and i_2 in the two circuits are connected by the two equations

$$\left.\begin{aligned} e &= \left\{R_1 + j\left(\omega L_1 - \frac{1}{\omega C_1}\right)\right\} i_1 - j\omega M i_2 \\ 0 &= \left\{R_2 + j\left(\omega L_2 - \frac{1}{\omega C_2}\right)\right\} i_2 - j\omega M i_1 \end{aligned}\right\} \quad \cdot\cdot \text{ (i)}$$

Writing $R_1 + j\left(\omega L_1 - \frac{1}{\omega C_1}\right) = Z_1$

and $R_2 + j\left(\omega L_2 - \frac{1}{\omega C_2}\right) = Z_2$

and eliminating i_1 gives

$$e = \left(\frac{Z_1 Z_2}{j\omega M} - j\omega M\right) i_2$$

which can be written

$$i_2 = \frac{e}{Z''} \qquad \cdot\cdot \qquad \cdot\cdot \quad \text{(ii)}$$

where Z'' is an impedance determining the secondary current for a given primary electromotive force.

$$Z'' = \frac{1}{j\omega M}\left(\omega^2 M^2 + Z_1 Z_2\right) \quad \cdot\cdot \quad \text{(iii)}$$

It is desired to find the locus of Z'' when the frequency of the electromotive force $e \cos \omega t$ is varied, for then the secondary current locus will be obtained at once by inversion.

The simplest case is obtained when the two circuits are tuned, so that $L_1 C_1 = L_2 C_2 = 1/\omega_0^2$ say, and the first step in a graphical representation of equation (iii) is to find the locus of $Z_1 Z_2$.

$$\begin{aligned} Z_1 Z_2 &= \left\{R_1 + j\left(\omega L_1 - \frac{1}{\omega C_1}\right)\right\} \\ &\qquad \left\{R_2 + j\left(\omega L_2 - \frac{1}{\omega C_2}\right)\right\} \\ &= R_1 R_2 - \left(\omega L_1 - \frac{1}{\omega C_1}\right)\left(\omega L_2 - \frac{1}{\omega C_2}\right) \\ &\quad + j\left\{R_2\left(\omega L_1 - \frac{1}{\omega C_1}\right) + R_1\left(\omega L_2 - \frac{1}{\omega C_2}\right)\right\} \end{aligned}$$

Expressing this vector equation in cartesian co-ordinates, the horizontal step x is the real part and the vertical step y is the imaginary, so that

$$x = R_1 R_2 - \left(\omega L_1 - \frac{1}{\omega C_1}\right)\left(\omega L_2 - \frac{1}{\omega C_2}\right)$$

$$y = R_2\left(\omega L_1 - \frac{1}{\omega C_1}\right) + R_1\left(\omega L_2 - \frac{1}{\omega C_2}\right)$$

---

[*] Simple Resonance Curves and their Modification by Valve Circuits, *E.W. & W.E.*, February, 1927, and March, 1927.

$$\text{Now} \quad \left(\omega L_1 - \frac{1}{\omega C_1}\right) = L_1\left(\omega - \frac{1}{\omega L_1 C_1}\right)$$

$$= L_1\left(\omega - \frac{\omega_0^2}{\omega}\right)$$

$$\text{and} \quad \left(\omega L_2 - \frac{1}{\omega C_2}\right) = L_2\left(\omega - \frac{\omega_0^2}{\omega}\right)$$

The equations become therefore

$$\left.\begin{aligned} x &= R_1R_2 - L_1L_2\left(\omega - \frac{\omega_0^2}{\omega}\right)^2 \\ y &= (L_1R_2 + L_2R_1)\left(\omega - \frac{\omega_0^2}{\omega}\right) \end{aligned}\right\} \quad \ldots \text{(iv)}$$

and on eliminating $\left(\omega - \dfrac{\omega_0^2}{\omega}\right)$:

$$y^2 = \frac{(L_1R_2 + L_2R_1)^2}{L_1L_2}(R_1R_2 - x) \quad \ldots \text{(v)}$$

This is the equation to the parabola drawn in Fig. 2, which is the locus with pole O of $Z_1\ Z_2$ when the circuits are tuned. Any ray such as OP represents Z_1Z_2 for a certain frequency. When ω is very small, it is seen from equations (iv) that x has a large negative value and y a large negative value. When ω is very large, x is negative and y positive. When $\omega = \omega_0$, $x = R_1R_2$ and y is zero. Evidently therefore as ω increases from a very small value, the point P describes the parabola in a counter-clockwise direction, passing through the vertex V at resonance. The actual values of ω round the parabola can be put in from either of the equations (iv).

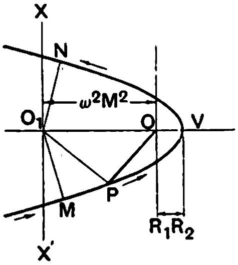


Fig. 2.

Returning to equation (iii), ω^2M^2 has next to be added to Z_1Z_2. With the circuits in common use in wireless the damping is small and the whole resonance effects take place with only a very small alteration of ω. As an approximation therefore ω^2M^2 may be considered to be constant, and if a new pole O_1 is found by measuring OO_1 to the left along the axis of the parabola, O_1P will be equal to the vector sum of ω^2M^2 and Z_1Z_2 for the particular frequency determining the location of P. Finally all rays O_1P are divided by ωM, or the scale is altered (considering ωM to be constant), and to multiply by $-j$ the diagram is turned clockwise through 90 degrees or the reference vector is turned counter clockwise to the position O_1X.

The magnitude of the secondary current is inversely proportional to the length of O_1P. With ω very small P is situated far to the left on the lower arm of the parabola and the current i_2 has a very small value. This is indicated in Fig. 3 in which $|i_2|$ and $|Z''|$ are plotted against ω. As ω increases P moves to the right and O_1P decreases (the current i_2 increases) until P reaches M, where O_1M is normal to the curve. Here the impedance $|Z''|$ is a minimum and the current i_2 a maximum. This is shown at ω_1 in the figure. From M, O_1P increases again until V is reached at ω_0, and here the current is a minimum. From V O_1P decreases until N is reached at ω_2, corresponding to a further current maximum, and finally O_1P increases without limit and the current i_2 decreases without limit. The well-known double hump resonance curve of two coupled circuits has been drawn.

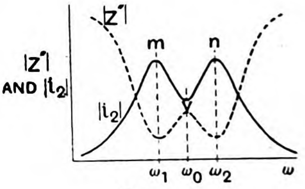


Fig. 3.

The parabola diagram shows clearly how the frequencies of the current humps are further and further apart as the coupling between the two circuits is increased. For an increase in the mutual inductance means the lengthening of OO_1 and the pushing of the normal points M and N further to the left along the arms of the parabola. On the other hand if the coupling is very loose O_1 will be very close to O, and there will only be a single maximum value of the current, as the only normal to the curve will be that through the vertex.

Phase changes too are brought out quite clearly. O_1X is the reference vector, that is the vector representing the voltage in the primary circuit. With very small values of ω, Z'' is 270 degrees behind O_1X and the secondary current leads the primary voltage by 270 degrees. At O_1X i_2 and V_1 are in phase. At the resonance value ω_0 (at O_1V) Z'' is 90 degrees behind O_1X, and the secondary current leads the primary voltage by 90 degrees.

Since OM and ON do not coincide with XO_1X^1, it is seen that the current at the maximum values is not exactly in phase or exactly 180 degrees out of phase with the primary voltage, but that as the coupling is increased this relationship becomes more and more nearly true. The phase of the current at the minimum value in the trough is always exactly 90 degrees ahead of the primary voltage.

Fig. 4 shows the secondary current locus obtained by inverting the parabola of Fig. 2 with pole O_1. With very loose coupling the locus of i_2 tends to become a cardioid, while with very tight coupling it approaches a pair of circles, as shown dotted in the figure. These extremes correspond in Fig. 2 to the pole O_1 approaching the focus of the parabola, and to the pole O_1, being so far to the left along the axis that the locus of P is very nearly straight while the current changes are most marked.

II. Other Types of Coupling.

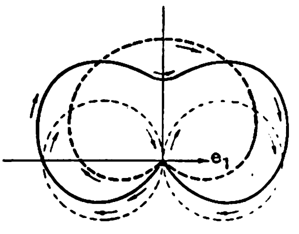


Fig. 4.

In the previous section the coupling of the two circuits was by mutual inductance. But quite similar results may be obtained with other methods of coupling.

(*a*) Take first the case of coupling by a common impedance Z_e which may be inductance, capacity or resistance or any combination provided that it is not in itself near resonance (see Fig. 5).

It is readily shown as in the first section that

$$Z'' = \frac{Z_1Z_2 - Z_e^2}{Z_e} \quad \cdots \quad \cdots \quad \text{(vi)}$$

where $Z_1 = R_1 + j\left(\omega L_1 - \frac{1}{\omega C_1}\right) + Z_e$

$$Z_2 = R_2 + j\left(\omega L_2 - \frac{1}{\omega C_2}\right) + Z_e.$$

Z_e must be included in the series impedances Z_1 and Z_2 of the two circuits in drawing the Z_1Z_2 parabola, but otherwise the proceeding is just the same.

If the common impedance has pure inductance

$$Z_e = j\omega l,\ Z_1 = R_1 + j\left\{\omega(L_1 + l) - \frac{1}{\omega C_1}\right\}$$

and $$Z_2 = R_2 + j\left\{\omega(L_2 + l) - \frac{1}{\omega C_2}\right\}$$

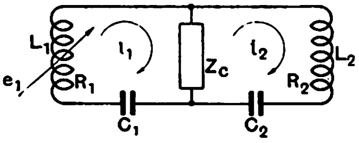


Fig. 5.

and l replaces M in equation (iii). The "coupling coefficient" $\tau = \frac{M}{\sqrt{L_1L_2}}$ thus

becomes $\dfrac{l}{\sqrt{(L_1 + l)(L_2 + l)}}$.

Similarly, if $Z_e = -\frac{j}{\omega C_e}$, or the coupling is by a pure condenser, ωM in (iii) is replaced by $1/\omega C_e$ and the circuits must be retuned for any alteration of C_e, to make

$$\sqrt{\frac{C_1 + C_e}{L_1C_1C_e}} = \sqrt{\frac{C_2 + C_e}{L_2C_2C_e}} = \omega_0.$$

If Z_e is a pure resistance R_e, $\overline{OO_1}$ is measured to the right of O, and a double hump cannot appear.

If the coupling impedance has resistance as well as inductance $Z_e = r + j\omega l$ say, Z_e^2 is also complex and the pole O_1 leaves the axis of the parabola. This is an interesting case. Although the circuits are retuned after the introduction of the coupling impedance, the current humps will have unequal maxima, as the lengths of the normals from O_1 to the curve must now be unequal, as is indicated in Fig. 6.

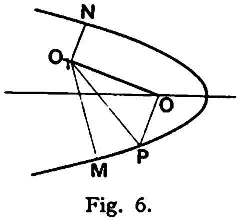


Fig. 6.

Here $OO_1 = Z_e^2$,

so that $\overline{O_1P} = O_1O + OP$
$= OP + O_1O$
$= OP - OO_1$
$= Z_1Z_2 - Z_e^2$

as required by (vi) (the additions are, of course, vectorial).

(*b*) Coupling by an impedance Z_c not common to the two circuits (Fig. 7) demands a little more algebra. The most interesting case for the wireless engineer is when the coupling is by a condenser C_c. In this case it can be shown that the impedance Z'' is obtained from the same parabola as before, which by a shift of the y axis to the vertex becomes

$$y^2 = \frac{(L_1R_2 + L_2R_1)^2}{L_1L_2}(-x)$$

but that the distribution of the ω points round the parabola and the pole from which the Z'' rays are to be drawn to the parabola are different.

The ω distribution is determined very nearly by the expression

$$\left.\begin{aligned} y&=2(R_1L_2+R_2L_1)(\omega-\omega_0+\omega_a) \\ \text{where}\quad \omega_a&=\tfrac{1}{4}\omega C_c\left(\frac{1}{C_1}+\frac{1}{C_2}\right) \end{aligned}\right\}$$

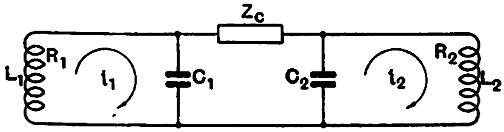


Fig. 7.

and the co-ordinates of the pole are

$$\left.\begin{aligned} -x_p&=R_1R_2+\tfrac{1}{4}\omega^2C_c^2L_1L_2\left(\frac{1}{C_1}+\frac{1}{C_2}\right)^2 \\ -y_p&=\omega C_c\left\{\tfrac{1}{2}(L_1R_2-L_2R_1)\left(\frac{1}{C_1}-\frac{1}{C_2}\right)\right\} \end{aligned}\right\}$$

The pole is thus only on the axis of the parabola when $C_1 = C_2$ (which since the circuits are tuned involves also $L_1 = L_2$), or when $L_1R_2 = L_2R_1$, or $\frac{R_1}{2L_1} = \frac{R_2}{2L_2}$, *i.e.*, when the decay factors of the circuits are the same.

To find the frequencies for the capacity coupling we simply subtract ω_a from each of the values found for the Z_1Z_2 parabola. But since ω_a depends upon the coupling condenser, the ω distribution is not fixed as in the previous cases, but varies as the coupling is varied.

(*c*) A still more complicated case arises when the coils L_1 and L_2 of Fig. 7 are coupled by a mutual inductance M, Z_c being a condenser. This is a very common case in all wireless circuits where coupling by mutual inductance is intended, and capacity coupling cannot be avoided. Under these circumstances C_c is small compared with C_1 and C_2, and if C_1 is not very different from C_2 and/or the decay factors of the circuits are the same, the same remarks as to the parabola apply as in the capacity case (*b*) above, with

$$-x_p = R_1R_2 + \{\omega M + C_c/\omega C_1C_2\}^2$$
$$-y_p = 0$$

and $$\omega_a = \tfrac{1}{4}\omega C_c\left(\frac{1}{C_1} + \frac{1}{C_2}\right).$$

Since M may be either positive or negative, it is seen that the effective coupling may be either increased or decreased by the presence of the stray capacity coupling.

Full details of these cases will be found in the author's paper, "A Vector Loci Method of Treating Coupled Circuits," *Proceedings of the Royal Society*, A, Vol. 117, 1928, pp. 331–350.

III. Circuits a Little Distuned.

The result of distuning the two circuits a little is also in general to throw the pole off the axis of the parabola, but in this case it is the pole of Z_1Z_2 which is displaced.

Let ω_1 and ω_2 be the values of $1/\sqrt{L_1C_1}$ and $1/\sqrt{L_2C_2}$ respectively, and suppose the coupling is by mutual inductance and is not very tight, so that the resonance changes take place with only a small change of ω, so that ω_1/ω and ω_2/ω are not very different from unity.

Thus the reactances of the two circuits are very nearly $2L_1(\omega - \omega_1)$ and $2L_2(\omega - \omega_2)$ respectively, and it can readily be shown that the locus of Z_1Z_2 is given in cartesian co-ordinates by

$$\left.\begin{aligned} x&=R_1R_2-4L_1L_2(\omega-\omega_1)(\omega-\omega_2) \\ y&=2L_1R_2(\omega-\omega_1)+2L_2R_1(\omega-\omega_2) \end{aligned}\right\} \quad \text{(vii)}$$

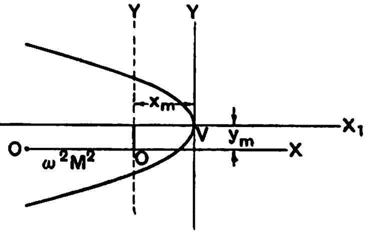


Fig. 8.

x has its largest positive value when $\omega = \frac{1}{2}(\omega_1 + \omega_2)$ and then the values of x and y are

$$\left.\begin{aligned} x_m &= R_1R_2 + L_1L_2(\omega_1 - \omega_2)^2 \\ y_m &= (L_2R_1 - L_1R_2)(\omega_1 - \omega_2) \end{aligned}\right\} \quad \text{(viii)}$$

Transferring to new axes $x^1=x-x_m$, $y^1=y-y_m$ (vii) becomes

$$x^1 = -L_1L_2\{(\omega_1+\omega_2)-2\omega\}^2$$

$$y^1 = (L_1R_2+L_2R_1)(\omega_1+\omega_2-2\omega)$$

and $y^{1\,2} = \dfrac{(L_1R_2+L_2R_1)^2}{L_1L_2}(-x^1)$.

Hence the locus of Z_1Z_2 when the circuits are a little out of tune is the same parabola as when they are in tune, but the pole is in a different position and the distribution of ω round the parabola is different. The former is fixed by equations (viii) and the latter by either of equations (vii).

Having found the locus of Z_1Z_2 the rest of the construction proceeds as before.

In the mutual inductance case ω^2M^2 is measured horizontally to the left to give the new pole O_1 in accordance with equation (iii) and so on. (Fig. 8.)

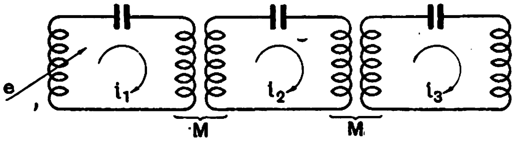


Fig. 9.

It is seen that generally O_1 is off the axis and the current humps will be of unequal height, but when y_m is zero, that is when the decay factors of the circuits are equal, the current humps are again equal.

IV. Extension to Three Coupled Circuits.

The graphical method can readily be extended to find the current in the last of the three coupled circuits shown in Fig. 9. The circuits are supposed to be identical and each coupled by a mutual inductance M. There is no coupling between the first and the third. With the currents i_1, i_2, i_3 taken as shown, and with each circuit consisting of coils and a condenser with combined inductance L and capacity C respectively and with total resistance R, so that the series impedance of each circuit is

$$Z = R + j(\omega L - 1/\omega C),$$

the following equations hold:

$$\left.\begin{aligned} e &= Zi_1 + j\omega Mi_2 \quad \ldots \quad \ldots \quad \text{(i)} \\ O &= j\omega Mi_1 + Zi_2 + j\omega Mi_3 \quad \ldots \quad \text{(ii)} \\ O &= j\omega Mi_2 + Zi_3 \quad \ldots \quad \ldots \quad \text{(iii)} \end{aligned}\right\} \ldots \quad 9$$

From (iii)

$$i_2 = -\frac{Z}{j\omega M}i_3 \quad \ldots \quad \ldots \quad 10$$

Putting this in (ii) gives

$$O = j\omega Mi_1 + \left(-\frac{Z^2}{j\omega M} + j\omega M\right)i_3$$

or

$$i_1 = \left(-\frac{Z^2}{\omega^2M^2} - 1\right)i_3 \quad \ldots \quad \ldots \quad 11$$

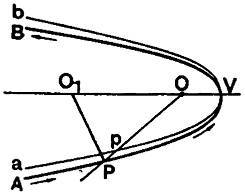


Fig. 10.

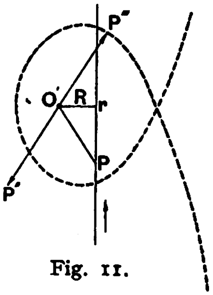


Fig. 11.

Putting 10 and 11 in (i) gives

$$e = \left(-\frac{Z^3}{\omega^2M^2} - Z - Z\right)i_3$$

$$= -Z\left(2 + \frac{Z^2}{\omega^2M^2}\right)i_3$$

$$= Z_3''\,i_3,\ \text{say} \quad \ldots \quad \ldots \quad \ldots \quad 12$$

where Z_3'' is the impedance from which the current in the last of three circuits is to be obtained from the electromotive force in the first. Z_3'' could be put into the form

$$-\frac{Z}{\omega^2M^2}\{2\omega^2M^2 + Z^2\} \quad \ldots \quad 13$$

Starting with the parabola Z^2 we have to find a new pole distance $2\omega M^2$ to the left along the axis instead of ω^2M^2 as in the case of the two circuits. Finally, we have to multiply by $-Z/\omega^2M^2$. It appears therefore that with a given coupling the resonance curve will extend over a greater ω range, and that the assumption that ω^2M^2 is constant will lead to greater errors, and this will be still further accentuated when the number of circuits is still further increased.

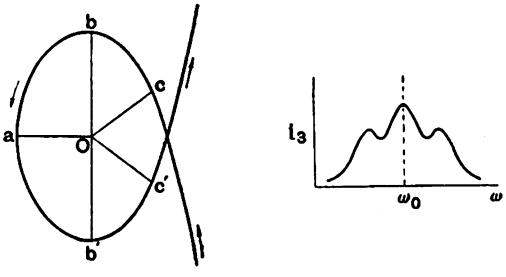
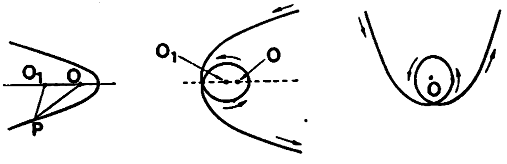


Fig. 12a and b.

It is better, therefore, to make the construction quite accurate by starting with the expression

$$Z_3'' = -Z\left(2 + \frac{Z^2}{\omega^2 M^2}\right) \quad .. \quad 14$$

and distorting the parabola $Z^2/\omega_0{}^2M^2$ by multiplying each ray by the corresponding value of $\omega_0{}^2/\omega^2$. Thus in Fig. 10, $apVb$ is the parabola $Z^2/\omega_0{}^2M^2$, with pole O, and Op represents $Z^2/\omega_0{}^2M^2$ for a certain value of ω. P is now found on Op or Op extended, so that $OP = \frac{\omega_0{}^2}{\omega^2} \times Op$, so that OP is the ray representing Z^2/ω^2M^2 at the value of ω chosen. In this way the distorted parabola AVB with pole O is the true locus of Z^2/ω^2M^2. To add 2 to each ray we find a new pole O_1 distant 2 from the old one. It remains to multiply by $-Z$. The locus of Z is as shown in Fig. 11, and if the ω value at P^1 in Fig. 11 is the same as that of P in Fig. 10, we have to multiply the vector O_1P, by the vector $O'P'$ and by -1. The length of $O'P''$ is made equal to the product of the lengths of $O'P'$ and O_1P, and the angle $rO'P''$ is made equal to the sum of the angles $rO'P'$ and VO_1P. Finally, $P''O'$ continued to P''', where $O'P''' = P''O'$ gives a point P''' on the required locus.



(a) (b) (c)

Fig. 13.

The complete locus takes the form shown in Fig. 12a, giving maximum impedances at b and b' and minimum at a, c and c', thus leading to the three hump curve of Fig. 12b.

V. Four and More Circuits.

The process can quite readily be extended to four and more coupled circuits. With four circuits linked as in Fig. 9 the circuital equations are

$$\left.\begin{aligned} e &= Zi_1 + j\omega Mi_2 \\ O &= j\omega Mi_1 + Zi_2 + j\omega Mi_3 \\ O &= j\omega Mi_2 + Zi_3 + j\omega Mi_4 \\ O &= j\omega Mi_3 + Zi_4 \end{aligned}\right\}$$

and these solved for i_4 give

$$e = \frac{j}{\omega^3M^3}\left[(\omega M)^4 + Z^2\{3(\omega M)^2 + Z^2\}\right]i_4$$
$$= Z_4''i_4$$

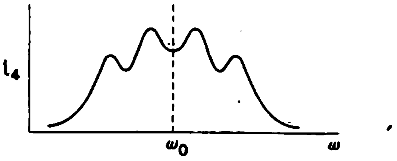


Fig. 14.

$$\text{or } Z_4'' = j\omega M\left[1 + \frac{Z^2}{\omega^2M^2}\left\{3 + \frac{Z^2}{\omega^2M^2}\right\}\right]$$

The successive steps in the graphical construction are indicated in Fig. 13. Starting with the distorted parabola Z^2/ω^2M^2, pole O, a new pole O_1 is found distance 3 to the left. The locus of

$$\frac{Z^2}{\omega^2M^2}\left\{3 + \frac{Z^2}{\omega^2M^2}\right\}$$

is found by multiplying vectors such as OP and O_1P. This gives the curve of Fig. 13b, pole O. Unity is added by finding a new pole O_1, so that $O_1O = 1$, and finally each ray is multiplied by $j\omega M$ to give the final locus shown in Fig. 13c. This results in the four hump resonance curve of Fig. 14.

The process can be continued indefinitely. Figs. 15 and 16 indicate the forms of the loci for five circuits and six circuits respectively drawn from the expressions

$$Z_5'' = Z\left[3 + \frac{Z^2}{\omega^2M^2}\left\{4 + \frac{Z^2}{\omega^2M^2}\right\}\right]$$

$$\text{and} \quad Z_6'' = -j\omega M\left[1 + \frac{Z^2}{\omega^2M^2}\left\{6 + \frac{Z^2}{\omega^2M^2}\left(5 + \frac{Z^2}{\omega^2M^2}\right)\right\}\right]$$

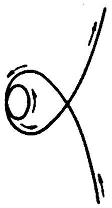


Fig. 15.

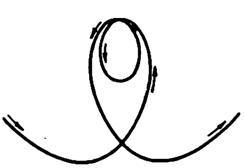


Fig. 16.

Microphone Amplifiers and Transformers.

By H. L. Kirke.

(Concluded from page 370 *of July issue.)*

Having dealt with the input and output transformer question, it is important to consider the components of the resistance or choke-capacity stages.

Inter-valve Condensers.

Distortion of the frequency characteristic may occur due to the use of too small inter-valve coupling condensers. Consider the circuit shown in Fig. 13. The reactance of the coupling condenser C will be negligible compared with R_2 at all except very low frequencies. Thus for medium and high frequencies the voltage variation produced at the anode of the first valve will be equal to

$$\frac{R_3}{R_0 + R_3}\mu\, v_g, \text{ where } R_3 = \frac{R_1 R_2}{R_1 + R_2}$$

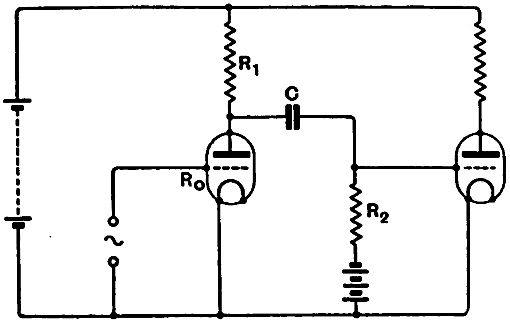


Fig. 13.

μ is the magnification factor of the valve and v_g is the voltage applied to the grid. In general, R_1 is large compared with R_0, and R_2 is large compared with R_1; thus the external impedance R_3, which determines the magnification for a given valve, is nearly equal to R_1 (if $R_2 = 5\ R_1$, then $R_3 = 5/6\ R_1$), and appreciable changes in R_2 produce only small changes in R_3 and consequently in the magnification. Now at some low frequency the reactance of C_2 may be appreciable, say equal to $1/5\ R_2$, and thus the external impedance R_3 is increased, but only very slightly. The increase in magnification due to this cause is so small that it can be neglected compared with the reduction of voltage across R_2 due to the reactance of C being in series with R_2. The value of r can thus be obtained approximately by assuming that the anode voltage variation is constant at all frequencies. The circuit can then be re-drawn as in Fig. 14, where e_a is the anode voltage variation.

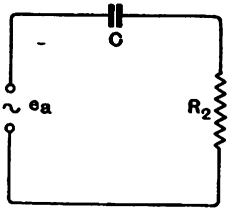


Fig. 14.

Now, at a medium frequency, where the reactance of C is negligible, the voltage across R_2 is equal to e_a.

At a low frequency, let the reactance of C be X_c.

Then the voltage across R_2 is

$$\frac{R_2}{\sqrt{R_2^2 + X_c^2}} e_a.$$

The reproduction factor is thus:

$$r = \frac{R_2}{\sqrt{R_2^2 + X_c^2}} \cdot \frac{e_a}{e_a} = \frac{R_2}{\sqrt{R_2^2 + X_c^2}}$$

As an example, if $R_2 = 1{,}000{,}000$, then for a value of r of 0.99 at a frequency of 50 p.p.s. (ω=314) :—$0.99 = \frac{10^6}{\sqrt{10^{12} + X_c^2}}$

from which $X_c = 139{,}200$ ohms.

thus C=0.023 mf.

For R_2=100,000, then, for r to be 0.99 at 50 p.p.s., C must be 0.23 mf.

In practice, however, it is usual to make the cut-down due to intervalve condensers small, *i.e.*, the reproduction factor high, such as 0.995 at 50 p.p.s.

Feed-back Due to Inter-electrode Capacity.

The feed-back from anode to grid of an amplifying valve may cause distortion of the frequency characteristic. Referring to Fig. 15(a), if e_p be the actual voltage variation at the anode (assumed sinusoidal) and e_g the voltage fed back from the anode to the grid through the inter-electrode capacity of the valve, then $e_g = \frac{R_2}{R_2 + \frac{1}{j\omega C}} e_p$,

where R_2 is the total effective resistance between grid and filament, including the

A.C. resistance and anode resistance associated with the preceding valve, if any.

The effective voltage on the grid necessary to produce e_p is $e^1_g = -\frac{e_p}{M}$ where

$$M = \frac{R_1}{R_1 + R_A}.$$

Then if the total voltage to be applied to the grid is v_g, then $v_g + e_g = e^1_g$.

$$\therefore v_g + \frac{R_2}{R_2 + \frac{1}{j\omega C}} \cdot e_p = -\frac{e_p}{M}$$

$$\therefore v_g = -e_p\left[\frac{1}{M} + \frac{R_2}{R_2 + \frac{1}{j\omega C}}\right]$$

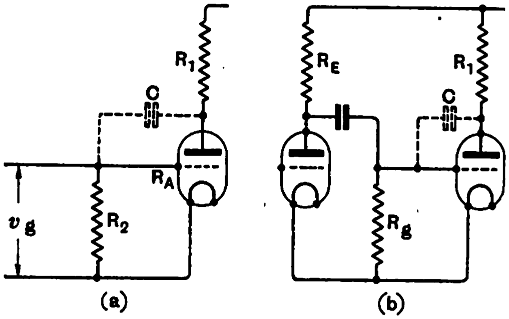
∴The effective amplification of the stage

$$M_1 = -\frac{e_p}{v_g} = \frac{1}{\frac{1}{M} + \frac{R_2}{R_2 + \frac{1}{j\omega C}}}.$$

Put

$$\frac{R_2}{R_2 + \frac{1}{j\omega C}} = a. \quad \therefore M_1 = \frac{1}{\frac{1}{M} + a} = \frac{M}{1 + Ma.}$$

At low frequencies the reactance $\frac{1}{\omega C}$ will be so large that the feed-back is negligible and the amplification of the stage is M. At high frequencies the amplification of the stage is $M_1 = \frac{M}{1 + Ma}$.



(a) (b)

Fig. 15.

The reproduction factor r is thus :—

$$r = \frac{M_1}{M} = \frac{1}{1 + Ma}$$

$$\text{where } a = \frac{R_2}{R_2 + \frac{1}{j\omega C}}$$

from which

$$r = \frac{1}{\sqrt{\frac{1 + \omega^2 R_2^2 C^2 \quad (2M + M^2)}{1 + \omega^2 R_2^2 C^2}}}$$

numerically.

From this expression it will be seen that the reproduction factor is reduced as either of the quantities $\omega_2 R_2$, C or M is increased. As ω is proportional to the frequency it is apparent that r is reduced as the frequency is increased, and so if the effect is appreciable it will result in a loss of high frequencies.

In practice it is found impossible to use valves having a magnification factor greater than 25 without an appreciable loss of high frequencies due to this cause.

When the stage is preceded by another resistance-coupled stage, as in Fig. 15(b), the value of R_2 is made up of the grid leak R_g, the preceding anode resistance R_E, and the A.C. resistance of the previous valve R_A, all in parallel. Since, in general, R_g and R_E are several times greater than R_A, the value of R_2 is practically determined by R_A. Thus when using two or more high magnification valves in cascade the value of R_2 is large due to the high impedance of these valves; consequently all the three factors R_2, C and M are large, so increasing the amount of feed-back.

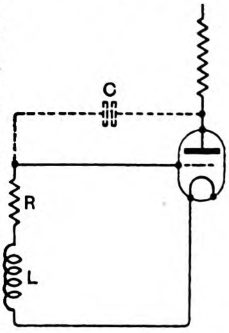


Fig. 16.

If the impedance between grid and filament is not a pure resistance, but has a positive phase angle, conditions may arise in which the feed-back produces reaction and not anti-reaction. Consider the case of Fig. 16. The anode voltage variation e_p is displaced 180 degrees from the effective grid voltage variation e_g^1. The feed-back voltage e_g will be ahead of the anode voltage e_p, the phase angle approaching 90 degrees as $\frac{1}{C\omega}$ becomes large compared with R_2. The angle can never exceed 90 degrees. Now if R_2 be replaced by a resistance R and inductance L in series, then at frequencies below $f = \frac{1}{2\pi\sqrt{LC}}$, the reactance $\frac{1}{C\omega}$ exceeds the inductive reactance $L\omega$ and the current in the circuit is ahead of the voltage e_p. The voltage e_g, however, will be ahead of the current, since the grid filament impedance has a positive phase-angle and it is possible for e_g to lead e_p by more than 90 degrees, thus producing reaction and not anti-reaction.

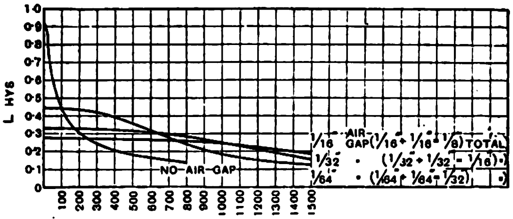


Fig. 17.—*Curves of inductance of stalloy core coil for various air gaps and D.C. currents for 1,000-turn coil.*

Effect of D.C. on Transformers.*

While static curves for iron show that values of flux density up to 10,000 lines per sq. cm. do not saturate the iron, the effect on the dynamic characteristic is considerable. The effect of D.C. flux on iron is generally to reduce the permeability, unless the value of D.C. flux is small. This reduces the effective inductance; resulting in a considerable increase in the leakage coefficient $\frac{L_3}{L_1}$, which in turn reduces proportionally the band of frequencies for which a transformer can be designed. The curves of Fig. 17 show the effect of D.C. flux on a stalloy core having a cross sectional area of 5.5 sq. cms. approximately a length of magnetic path (in iron) of 18 cms. and 1,000 turns, with various values of air-gap.

If a transformer or choke be made with a closed core having 1,000 turns, it will be seen that its inductance with no D.C. through the winding will be 0.92 henry. Now if a direct current of 50 milliamps flows through the winding the inductance will be reduced to 0.6 henry, and for a current of 100 milliamps the inductance will be only 0.44 henry. For a given core the D.C. flux depends upon the ampere-turns; so that for a transformer of 5,000 turns the percentage reduction of inductance due to saturation for a current 10 milliamps is the same as that produced by 50 milliamps in 1,000 turns, *i.e.*, $\frac{0.6}{0.92} = 65$ per cent. Consider a circuit as shown in Fig. 18, which may represent the last stage of a microphone amplifier. Let the A.C. resistance of the valve be 6,000 ohms and the output transformer be designed for matched impedance so that the load R_L when referred to the primary of the transformer will have the value 6,000 ohms. Then if a cut-down to 0.95 at 50 p.p.s. is desired the value of primary inductance can be found from Fig. 5. R_4 is 3,000 ohms, and $\omega_1 L_1$ must be three times R_4, *i.e.*, 9,000 ohms.

$$\therefore \quad L_1 = \frac{9{,}000}{2\pi \times 50} = 28.6 \text{ henries.}$$

For 28.6 henries with no D.C., 5,670 turns will be required. Now if the valve normally operates with an anode current of 20 milliamps the ampere-turns will be 113.4, and the reduction of inductance will be to $\frac{.41}{.92} = 44.6$ per cent., the actual inductance being 12.7 henries. This will obviously produce a much worse value of cut-down at 50 p.p.s. than $r = 0.95$.

If the turns be increased in the ratio $\sqrt{\frac{28.6}{12.7}}$ so that the number of turns is 8,520, then with no D.C. the inductance is 64.5 henries, and with 20 milliamps D.C. the inductance is 21.2 henries. Thus, although the turns have been increased the inductance under working conditions is still not sufficient to give the performance $r = 0.95$ at 50 p.p.s. and if the turns be still further increased the loss of high frequencies due to leakage will be serious.

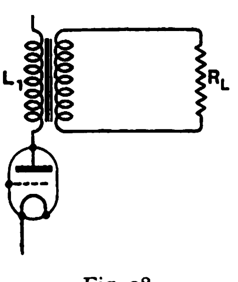


Fig. 18.

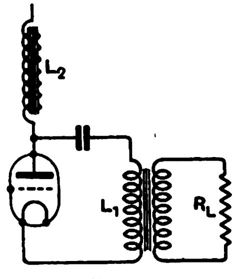


Fig. 19.

---

[*] *See* G. W. O. Howe, Design of Choke Coil and Transformers to carry Direct Current, *E.W. & W.E.*, Feb., 1928.

In order that no D.C. shall flow in the output transformer it may be choke-fed, as shown in Fig. 19. The choke L_2 is effectively in parallel with the transformer primary L_1, and so its inductance must be kept high, as the total reactance of L_1 and L_2 in parallel must be three times R_4 if the reproduction factor r is to be 0.95 at 50 p.p.s. If the core of the choke is similar to that of the transformer, then there is double the winding space available and so the number of turns may be considerably increased, as leakage has no significance in a choke. If the turns be increased three times, the inductance is increased nine times for a closed core or 4.5 times for a core having a 1/32 in. air gap (the introduction of a 1/32 in. air gap approximately doubles the reluctance of the magnetic path). If then the choke be made with $3 \times 5{,}670 = 17{,}010$ turns and with an air gap of 1/32 in., its inductance will be $4.5 \times 28.6 = 129$ henries. Then with an anode current of 20 milliamps the ampere-turns will be 340.2. Reference to Fig. 17 shows that for a core with a total air gap of 1/32 in. the inductance of the core with 340.2 ampere-turns is $\frac{.41}{.44}$ of its inductance with no D.C. Hence the inductance of the choke will be $\frac{.41}{.44} \times 129 = 120$ henries. Then since the combined inductance of L_1 and L_2 must be 28.6 henries, L_1 will be 37.6 henries and the turns required will be 6,500. In this case, therefore, the value $r = 0{\cdot}95$ at 50 p.p.s. is actually obtained with 6,500 turns on the

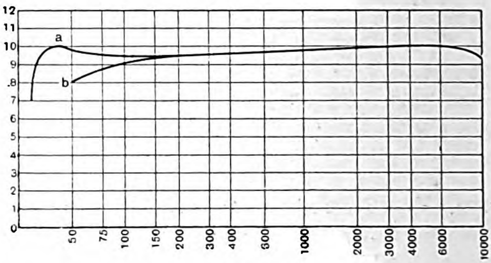
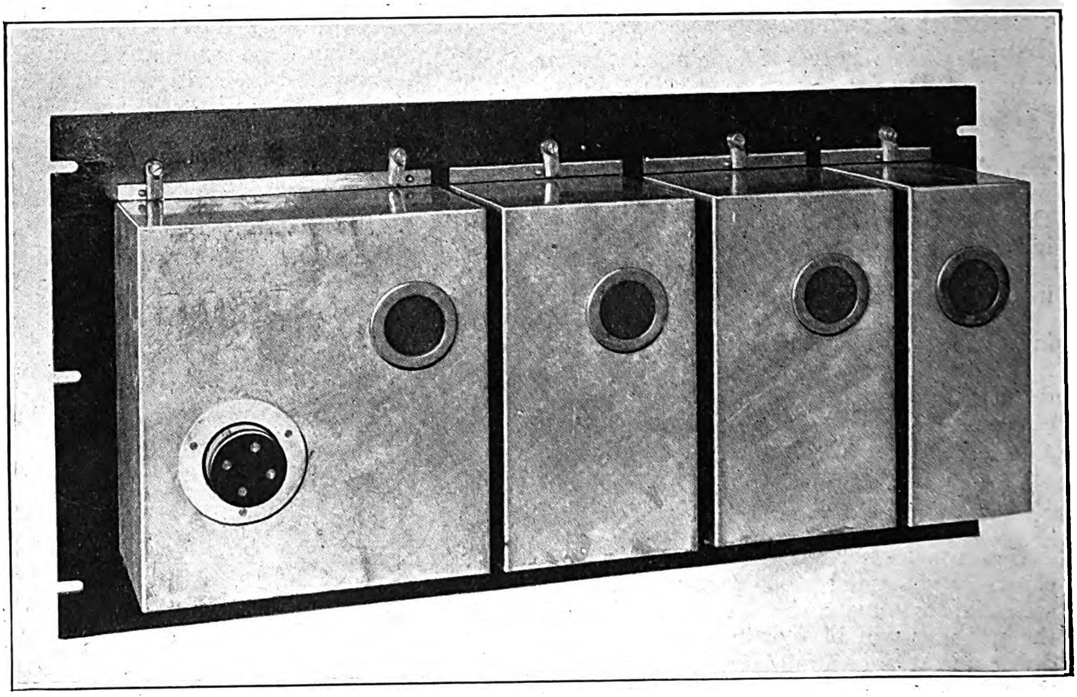


Fig. 20.



Studio Microphone Amplifier with screening covers.

transformer primary, whereas by passing the D.C. through the transformer it could not be obtained even with 8,520 turns. Conditions can be steadily improved by increasing the inductance of the choke until the point is reached when its D.C. resistance causes too large a voltage drop. In practice the choke can be made so that its inductive reactance at 50 p.p.s. is about 7 to 10 times the A.C. resistance of the valve.

This method of choke-feeding the output stage has the additional advantage that the load current does not pass through the choke and back through the H.T. supply; this reduces any tendency to reaction or cross-talk effects due to common resistance in the H.T. supply when a number of amplifiers have a common H.T. supply.

The value of the coupling condenser should be chosen so that its reactance at all frequencies is low in comparison with the resultant primary impedance, plus the valve resistance, as described under intervalve condensers.

The value of this condenser can be chosen so that it assists the output at low frequencies where the output is low due to lack of self-inductance in the primary winding. If the values are chosen carefully the frequency characteristic may be improved as shown in Fig. 20, where " a " is a curve with the condenser at the critical value and " b " is the curve for a condenser of negligible reactance. The effect is produced by the condenser reactance tending to reduce the resultant reactance component of the loaded transformer, so increasing the current and consequently the P.D. At low frequencies (near resonance) the values must be so chosen that the circuit is always effectively damped by the valve A.C. resistance and transformer load and/or losses.

The method has the disadvantage that the phase shift is considerable—this will be particularly bad if there are several such stages in the chain. It will be seen that the total impedance will be reduced at frequencies at which the effect occurs, and this again will tend to reduce the maximum output from the last stage due to the alteration of the dynamic characteristics of the valve. A further disadvantage is that the magnetising current will be increased, bringing distortion where values of flux density are so great as to vary the permeability over the cycle. This point will be dealt with later.

Resistance and Choke-Capacity Coupling.

The magnification obtainable from a resistance-coupled stage is given by the well-known expression $M = \frac{R_3 \mu,}{R_3 + R_A}$ where R_3 is the total resistance of R_1 and R_2 in parallel (Fig. 21), μ the magnification factor and R_A the A.C. resistance of the valve, C being so large that its reactance is negligible at all frequencies within the band. M approaches the value μ as R_3 is made large compared with R_A.

With choke coupling (Fig. 22), if the inductance of the choke be fairly high, then, at a medium frequency f_2, $M = \frac{R_2}{R_2 + R_A}$, since $\omega_2 L_1$ is very large. The reproduction factor at a low frequency f_1 is obtained in the same way as explained with reference to Figs. 3 and 4—*i.e.*—

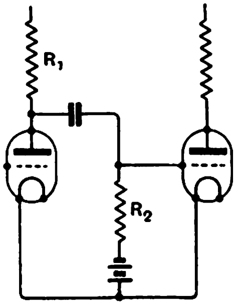


Fig. 21.

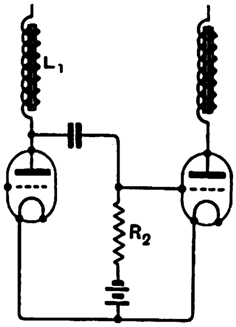


Fig 22.

$$r = \frac{1}{\sqrt{1 + \left(\frac{R_4}{\omega_1 L_1}\right)^2}} \quad \text{where } R_4 = \frac{R_2 R_A}{R_2 + R_A}$$

$$\text{or } \frac{\omega_1 L_1}{R_4} = \frac{r}{\sqrt{1 - r^2}}$$

If $R_A = 20,000$ ohms and $R_2 = 1,000,000$ ohms, then for

$r = .98$ at 50 p.p.s., $L = 308$ henries.
$r = .99$ at 50 p.p.s., $L = 440$ henries.

These figures indicate how difficult it is to make a choke suitable for a valve of as high an impedance as 20,000 ohms if several stages of such choke coupling are to be used.

The great advantage of choke coupling is that the drop of H.T. voltage is low and the H.T. at the anode therefore high, so that the maximum distortionless output is greater than with resistance coupling for a given valve. Alternatively, a valve having a higher resistance and magnification factor may be used with choke coupling to give the same value of distortionless output as a low-resistance low-magnification valve with resistance coupling. The magnification obtainable with a given valve—particularly a high impedance valve—is greater with choke coupling as the H.T. at the plate is higher and the choke can be made of higher impedance than the resistance. In any case, the choke has more effect than a resistance having the same impedance as the choke; this will be seen from Fig. 23, which shows the magnification coefficient "x" of a valve against ratio of external to internal impedance $x. = \dfrac{1}{1 + \dfrac{R_0}{Z}}$ for a constant H.T. voltage between anode and filament.

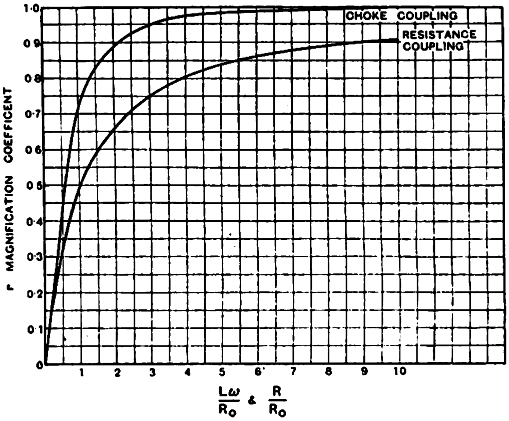


Fig. 23.

Comparison of Resistance Coupling, Choke Coupling and Transformer Coupling.

The use of transformer coupling must be restricted to valves of fairly low impedance, say 8,000 ohms, if a good performance is to be obtained; and even so, if there are several such stages in cascade, the loss of low frequencies is bound to be serious unless transformers of very considerable weight and bulk are used. As far as frequency performance is concerned choke coupling is a considerable improvement on transformer coupling, since for a given size of core there is double the winding space and consequently the possibility of getting at least four times the inductance. However, from the figures given it will be seen that if a very good performance is to be obtained in an amplifier having, say, five stages, then the chokes must be so large that they are not worth while. For a good overall curve from a multi-stage amplifier resistance coupling is the only solution, and this is the only form of inter-valve coupling that can be used in microphone amplifiers for broadcast purposes.

Distortion of the Amplitude-magnification Characteristic.

When an amplifier fails to amplify equally at all amplitudes, it may be said to be a non-linear amplifier. The effect of this is that currents non-existent in the input waveform will be produced in the output. These currents are odd or even multiples of the fundamental frequencies, dependent on the type of distortion. This form of distortion is far more unpleasant than distortion of the frequency characteristic of the same order of magnitude.

Distortion may be caused by valves, transformers and chokes. Valve distortion is of two classes: firstly, due to grid current; secondly, by non-linear anode current characteristics.

If grid current flows due to the grid being allowed to become positive relative to the filament for a portion of the cycle, then during that portion of the cycle the effective grid-filament impedance is low, whereas normally it is very high. If the previous stage is a resistance or choke-coupled stage, then this low grid-filament impedance, if it is comparable with the preceding anode impedance, will materially reduce the magnification of the preceding stage over that portion of the cycle, so that the wave-form is distorted. The same applies if the grid is fed from a transformer, the low grid-filament impedance damping the secondary to such an extent that the magnification is materially reduced. In resistance or choke-capacity coupling the grid current leaves an extra negative charge in the inter-valve condenser which will discharge at a rate depending on the time constant of the circuit. If the circuit is arranged so that R_2 is small compared with the grid-filament impedance when the grid is positive, then grid current will not cause distortion; but this is obviously a very inefficient arrangement, since it puts such a low effective resistance in the anode circuit of the preceding valve. In general it is good practice to avoid grid current in all low frequency stages.

The second type of valve distortion is that due to the non-linearity of the plate current characteristics of the valve. This can be avoided by :—

(a) Having a large factor of safety in each stage.

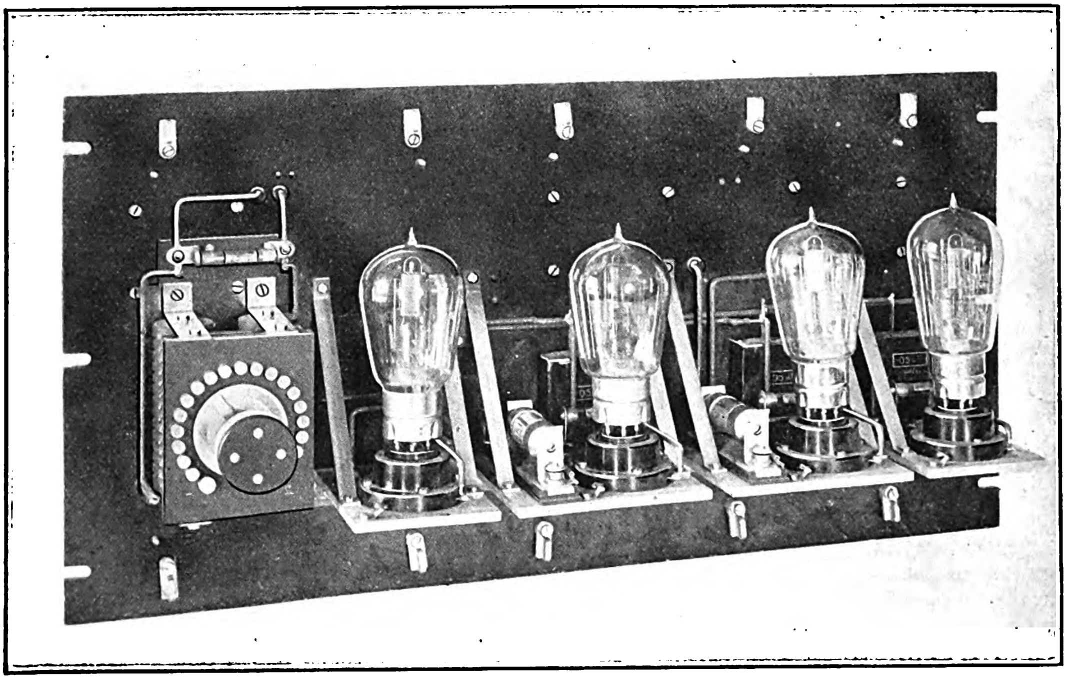
(b) Using relatively high impedance output circuits.

The non-linear characteristic gives the same effect as a generator with an internal resistance varying with amplitude of load. The ratio of output volts to input volts will therefore vary with amplitude unless the output impedance is high compared with the internal resistance; in resistance-capacity stages this is both convenient and efficient, as a high value of anode resistance gives a high value of magnification.

Iron Distortion.

All circuits having iron-cored inductance of any kind are a potential source of distortion. This is because the permeability μ varies with flux density B and magnetising force H.

Referring to Fig. 24, the E.M.F. e_p applied to the choke L_1 will be equal and opposite to the back E.M.F. produced by the changing flux in the choke, neglecting the D.C. resistance of the choke. Taking one extreme case: if R_0 is small compared with the impedance of the choke, then $e_p = e_1$; so that if e_1 is a sine wave, e_p will be a sine wave. The back E.M.F. is proportional to the rate of change of flux in the core, so that if ϕ is the flux, $e_p \propto \frac{d\phi}{dt}$. Therefore $\frac{d\phi}{dt}$, and consequently ϕ, must be sinusoidal. If B/H for the iron is not constant over the cycle, then ϕ/i_1 will not be constant, and therefore i_1



Studio Microphone Amplifier (three stages) without screening covers.

will not be a sine wave. In the other extreme case, if R_0 is large compared with the choke impedance, $i_1 = \frac{e_1}{R_0}$, thus i_1 is sinusoidal, and ϕ and therefore the back E.M.F. and thus e_p will not be sinusoidal.

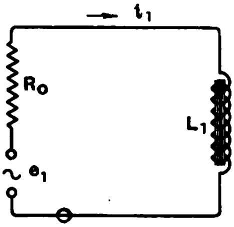


Fig. 24.

The practical case lies between these two extremes, so that, if R_0 is of the same order as the reactance of L_1, both e_p and i_1 are distorted. In the case of a transformer R_0 is the total resistance of the source of E.M.F. and the load across the transformer in parallel, as in the case of Figs. 3 and 4. The smaller R_0 the less the final distortion, since the output voltage across the secondary depends directly upon e_p and not upon i_1, so that when e_p is sinusoidal the output voltage is sinusoidal, although i_1 may be distorted. If the reactance of L_1 at some low frequency is made three or four times R_0 a Stalloy core may be worked at that frequency up to 4,000 to 5,000 lines/sq. cm., nickel-iron up to 2,100 lines/sq. cm., and Mumetal up to 1,500 lines/sq. cm. If this frequency is the lowest it is desired to transmit, no distortion will be introduced at any higher frequency, since for constant voltage output the flux density will decrease as the frequency increases and also $\frac{\omega L_1}{R_0}$ will increase with increasing frequency.

Magnification required in Amplifiers.

Most amplifiers are designed to have their outputs connected to a line. If a number of amplifiers are used in cascade with a line connecting the output of one amplifier to the input of the other, see Fig. 25, it might appear that a lack of magnification on one amplifier could be made up by an increase in magnification on one of the others. This, however, is not strictly true, as line noise and other interference introduce certain desiderata. The ultimate factor governing the amount of extraneous disturbance heard is the ratio of signal to such disturbances. This ratio must naturally be made high, because in practice on commercial lines noise cannot be reduced below a certain amount. In order that the ratio signal strength to noise shall be great, the signal strength or output from any amplifier should not be less than a certain amount. On the other hand, to prevent cross-talk on other lines the signal must not exceed 2.5 mA. This means that each and every amplifier must be capable of delivering a maximum R.M.S. current of 2.5 mA. to a line on any type of programme without distortion. This will determine the overall maximum magnification which must be obtainable between a microphone and a line, also the type of valve and H.T. voltage required for the output stage. It has been found that owing to low value of step-up of the input transformer, which is obtainable with a good frequency characteristic, the magnification has to be proportionately increased. For an amplifier having a good frequency characteristic for use with a Marconi-Reiss Microphone, sufficient amplification and adequate factor of safety as regards distortionless output power, four stages must be employed. The first two stages should be high magnification valves, the third a medium magnification valve and the last a low-resistance power valve; the high tension voltage may be 120 to 150 volts for short line work and 200 to 300 volts for long line work. A diagram of connections of an "A" amplifier is shown in Fig. 26.

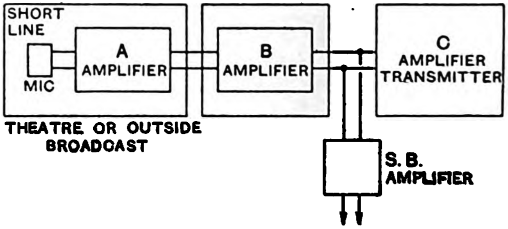


Fig. 25.—*Arrangement of Amplifiers between Microphone and Broadcast Transmitter.*

Intermediate amplifiers must have sufficient amplification to bring the power level up to normal before connecting to a line, *i.e.*, must make up for losses in the line, local circuit, correction or equalising apparatus, with always an adequate factor of safety.

Factor of Safety.

It is almost impossible to overdo the factor of safety on an amplifier. By factor of safety is meant the ratio of maximum output obtainable without distortion to average output; if the normal output is 2.5 mA. into a 500 ohm line, then the maximum peak value may be 20 mA. This at 500 ohms is 10 volts; if the transformation ratio is 5 : 1, the primary peak volts will be 50 and peak current 4 mA. Allowing a safety factor of 2 (at least) then the H.T. to the last valve would need to be 150 for a normal L.R. valve with an anode current of 10 mA. It is advisable, however, to exceed even this in special circumstances.

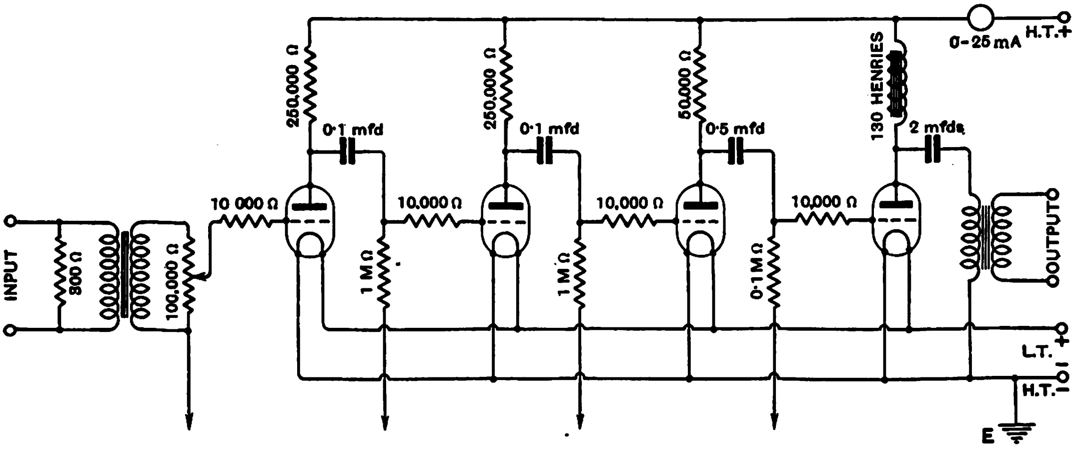


Fig. 26.—*Diagram of connections of "A" Amplifier.*

Mechanical Design.

In outside or theatre broadcast work it is necessary to make an amplifier comparatively portable and compact, but this need not be carried to excess, as, owing to weight of batteries, vehicular conveyance is usually required for transporting apparatus from one place to another.

It is of very great importance to choose valves for early stages which are non-microphonic and to arrange to have them suitably mounted; microphonic noises are of two kinds: those transmitted to the valve by mechanical vibration of the amplifier and those by air vibrations to the glass.

Other factors to be borne in mind are :—

(1) Mechanical strength.
(2) Accessibility for fault finding.
(3) Convenience of external connections.
(4) Screening.

Volume Control.

All amplifiers should be equipped with volume control. Where this is required for artistic fading-in the adjustments should be fine, not greater than an increment of 1.2 : 1 per step (in voltage amplification). For volume control the increment should not be greater than 1.4 : 1 per step. It has been found necessary to provide volume control over very wide ranges of amplitude to provide for extremes of programmes, and various circuit and line losses. Early amplifiers had a maximum variation of 100 : 1 for "B" amplifiers and about 10 : 1 for "A" amplifiers. It has been found that a variation of 10,000 : 1 is required with a complete fade-out for "B" amplifiers and a variation of 200 : 1 with a complete fade-out for outside broadcast "A" amplifiers.

The Future.

The present tendency is to eliminate all transformers, even input and output, unless transformers can be designed which are robust in every sense of the word and which are electrically good, *i.e.*, have good frequency characteristics. The difficulty with transformers will always be phase change of transients. It has been stated that this is unimportant, as the phases become changed due to acoustical reflections. A number of transformers may, however, change the phase very considerably, even more than 360 degrees, as the phase changes in each transformer are additive.

The Measurement of Small Variable Capacities at Radio-frequencies.

By *W. H. F. Griffiths, A.M.I.E.E., Mem.I.R.E.*

THE actual capacity of a small variable air condenser cannot be determined or stated with accuracy unless its leads and screening conditions to be employed subsequent to calibration are known and exactly set up at the time of calibration. That is to say, a small variable condenser cannot be calibrated precisely for capacity value unless the apparatus and circuit with which it is to be associated are known also.

Indeed, a statement of capacity for a small condenser (even if perfectly screened) is of little use if given at its terminals with no reference to the leads without which it cannot be used. Such a statement, moreover, cannot be made to include the distributed capacity and capacity to earth of any apparatus ultimately to be associated with the condenser.

The Difficulty of Calibrating Small Variable Condensers.

In Fig. 1, S_1 represents the metallic screening of the small variable condenser C to be calibrated; of its two terminals D and E the latter is joined electrically to this screen.

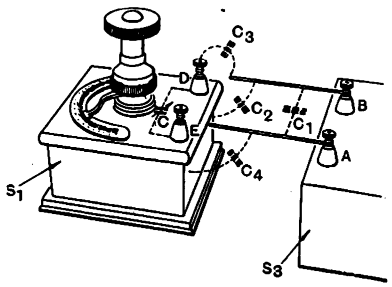
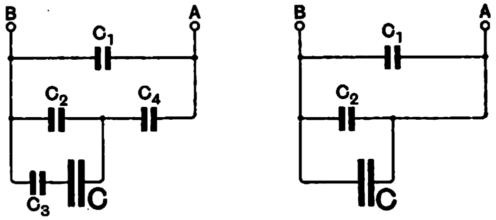


Fig. 1 (see also Fig. 2).

The earthy mass of the screening metal work of the measuring apparatus is indicated by S_3 and the two terminals A and B (the former earthy) are for the capacity to be tested.

Any method of test usually consists, in effect, of obtaining two values of capacity, one (C') prior to connecting the capacity to be measured and the other (C'') with the latter in circuit—the difference between the two values being taken as the required calibration value.

If, as shown in Fig. 1, two stiff self-supporting wires are taken from the measuring apparatus close to the terminals of the condenser C to be calibrated so that a minimum of alteration is made in the positions of those wires upon joining them to the terminals, it is seen that



PRIOR TO CONNECTING

CONNEOTED

$$C' = c_1 + \frac{c_4(c_3 + c_2)}{c_2 + c_3 + c_4} \qquad C'' = c_1 + c_2 + C.$$

Fig. 2.

$$C' = c_1 + \left\{ \frac{c_4\left(\frac{c_3C}{c_3 + C} + c_2\right)}{\frac{c_3C}{c_3 + C} + c_2 + c_4} \right\} \text{(see Fig. 2).}$$

If c_3 is small compared with C

$$C' = c_1 + \frac{c_4(c_3 + c_2)}{c_2 + c_3 + c_4}.$$

Upon connecting up the condenser C to be measured, provided that c_2 is not appreciably increased by doing so,

$$C'' = c_1 + c_2 + C.$$

Therefore the capacity actually measured will be

$$C'' - C' = C + c_2 - \frac{c_4(c_3 + c_2)}{c_2 + c_3 + c_4}.$$

Moreover, in addition to this uncertainty, the capacity c_4 is augmented prior to calibration by that between the mass of the screen S_1 and the earthy screening metal work S_3 of the measuring apparatus, since these two systems are not at the same potential. This augmentation of c_4 may be larger than that capacity itself, is certainly variable with varying proximity to the test set and, together with c_4, it is short-circuited upon joining up the condenser for calibration.

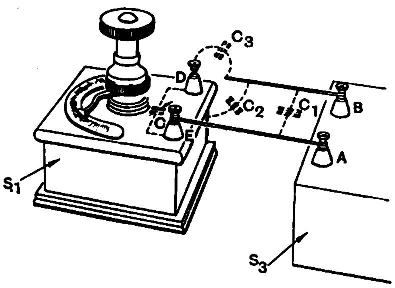


Fig. 3 (see also Fig. 4).

In order to eliminate this latter uncertainty a simplification may be effected by joining the low potential wire A direct to the earthy terminal E. The positions of the connecting wires prior to calibration (for the measurement of C') are now as indicated in Fig. 3 and it is seen that

$$C' = c_1 + c_2 + \frac{c_3 C}{c_3 + C} \text{ (see Fig. 4)}$$

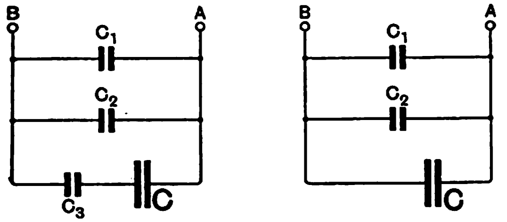
or, if c_3 is small compared with C

$$C' = c_1 + c_2 + c_3$$

and upon joining the B wire to terminal D

$$C'' = c_1 + c_2 + C.$$

The capacity measured in this case is therefore $C - c_3$, *i.e.* it is low by the amount of c_3.



PRIOR TO CONNECTING

$C' = c_1 + c_2 + c_3$

CONNECTED

$C'' = c_1 + c_2 + C$

Fig. 4.

But if c_3 is made sensibly zero by withdrawing wire B to make the gap at D large, then c_1 and c_2 will not be constant—they will be increased when connecting the wire B to terminal D thus making the capacity measured high by the amount of this increase.

The capacity C can be more easily defined and measured if rigid self-supporting wires or strips AE and BD are fitted to the terminals of the condenser being measured as shown in Fig. 5, and their ends arranged permanently so that the points A and B will exactly coincide with corresponding points of the apparatus ultimately to be associated with the condenser, and to which points *thin* wires AG and JH can be taken from the testing set. Even in this case, however, although the points A and B are sufficiently far from the screen S_1 to make c_1 and c_2 constant prior to, during, and subsequent to calibration, and although the gap capacity c_8 can be made small without greatly varying c_2, there is still the danger of a varying capacity c_6 to earthy bodies from the unscreened high potential lead DB.

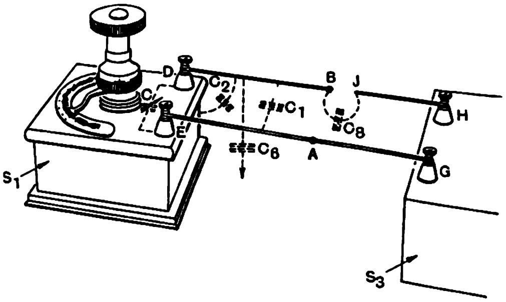


Fig. 5.

The obvious remedy for this is, of course, to let the low potential lead AE take the form of a tube concentric with DB and screening it to a point near to its end B. This would, however, too greatly augment the residual value of a variable air condenser of very low capacity.

The capacity c_6 to earth of the lead DB can, however, be made constant by placing below it a metal sheet S_2 which is joined electrically to the screen S_1 of the condenser and is, in effect, a continuation of it as shown in Fig. 6. Although the plate S_2 does not screen the high potential lead completely it is usually a great safeguard since it screens it from unknown and sometimes unseen earthy objects which chance to be under the surface of the laboratory table. Moreover, the lead and the apparatus which it associates with the condenser are remote from the operator whose body and hand during operation are, of course, at the front *F* of the variable condenser which should, for this reason, be perfectly screened in this direction.

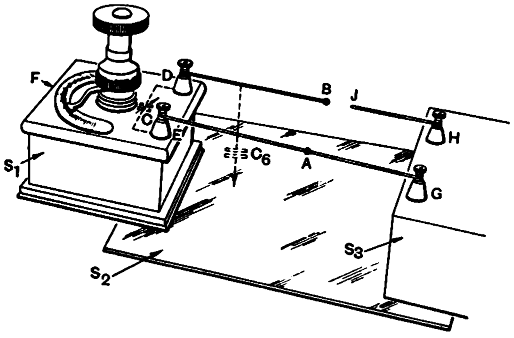


Fig. 6.

Even after these precautions have been taken in order to obtain as nearly as possible the actual capacity of the variable condenser up to the points *A* and *B* this value is augmented immediately upon the completion of the circuit as, for instance, in the case of the simple resonant wavemeter circuit of Fig. 7 which is, perhaps, to the radio engineer, the best-known example of the augmentation of the capacity of a calibrated condenser by the unknown capacity of apparatus associated with it.

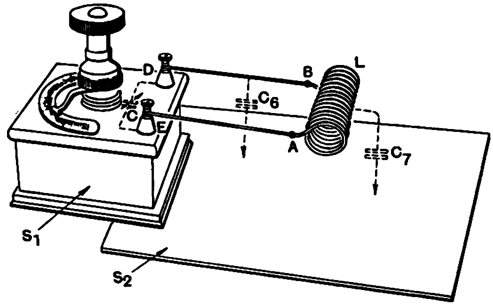


Fig. 7.

Slope Calibration.

In this case, since capacity augmentation to an unknown extent always occurs, it is not always necessary to know the *actual* capacity of the condenser. It should be quite sufficient to know the capacity "differences" throughout its range.

Moreover, this method of variable air condenser calibration can be made to ensure that the linear portion of the condenser scale only is used. In calibrating by this method a "false zero" of capacity is fixed arbitrarily near the minimum capacity end of the scale, but sufficiently far from it to be certain of avoiding the non-linear portion.

In this way the constant "b" is thus, in effect, eliminated from the condenser law $C = a\theta + b$ and added to the unknown self-capacity c_s of the coil and leads. This change of scale is indicated graphically in Fig. 8.

It will be seen later that a capacity difference or "slope" calibration from this arbitrary "zero" can be readily effected with precision although the actual capacity at any point of the condenser scale is difficult to determine to the same degree of accuracy. For the majority of work for which a precisely calibrated variable air condenser is required, a statement of differences or of degree of conformity to slope (tan α or $a\theta$) will suffice.

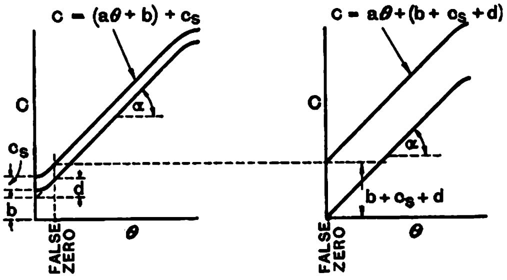


Fig. 8.

A difference calibration is certainly all that is needed if the condenser is to be used as a standard in a simple resonant circuit or in a symmetrical A.C. bridge of the Wien form. For in the latter case one can usually balance initially the "zero" of the standard condenser and in the former its "zero" value may be included in the distributed capacity (self-capacity and capacity to earth) of the coil associated with it and the whole determined directly by an accurate method.

Frequency the only Precise Measurement that can be Effected on a Simple Resonant Circuit.

It is interesting to note that in the case of the simple resonant circuit a similar trouble exists with the determination of the inductance of a small coil if the condenser with which its circuit is to be completed is unknown. In this case as with the calibration of a small condenser the only exact measurements that can be effected are those made by a frequency standard on the whole assemblage of apparatus, the effective inductance as well as the uncertain residual capacity being determined by using the known law connecting frequency and capacity.

A Precise Method of "Slope Capacity" Calibration.

A method of determining exact capacity differences which has been employed by the author and which may be original in detail will now be described.

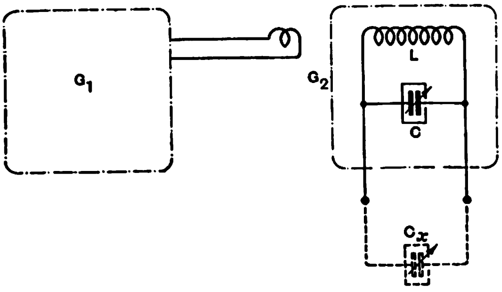


Fig. 9.

The method owes its high degree of accuracy not only to the fact that the capacity change is determined in terms of frequency change of a heterodyne beat note, but also to the fact that the capacity increments throughout the whole range of the condenser are determined in terms of one standard tuning fork only—a calibrated low-frequency oscillator not being required. Moreover, it will be seen later that only one standardised radio frequency is required even for the highest possible accuracy.

In Fig. 9, which is a simplified diagram of apparatus set up for such a calibration, G_1 is a radio-frequency triode generator (or heterodyne wavemeter) for which a frequency calibration exists and G_2 is one for which no *frequency* calibration is necessary, but the variable condenser C of which is calibrated for capacity (a slope calibration is all that is needed).

C_x is the small screened variable air condenser to be calibrated and this is connected directly across C without any preliminary determinations having been made. C_x is first set at a low scale reading (preferably just on the linear portion of its scale) and this reading is noted or marked accurately as its " zero " from which the calibration is to commence.

Since C is calibrated in capacity throughout its scale it is possible to determine the self-capacity (and, incidentally, the effective inductance) of G_2. This should be effected, in the manner to be described later, with C_x connected across C and set to its " zero" reading.

Having found a value C_s for this composite self-capacity it should, of course, be added to the calibration value of C in order to give the actual capacity of the whole circuit at any scale reading.

G_1 is now set oscillating at a frequency for which a *frequency* calibration exists—a frequency which is convenient also for the production of the desired heterodyne beat notes for the desired capacity changes. While still keeping C_x set to its " false zero " reading, C is adjusted until a heterodyne beat note of 500 cycles per second is obtained—the note being adjusted exactly to this frequency by the aid of the slow synchronisation beating between its first even harmonic and a tuning fork standardised at 1,000 cycles per second.

For this setting of G_1, C and C_x the values of frequency, capacity and inductance are known.

The value of C_x is now increased until the heterodyne beat note is raised to 1,000 per second exactly by comparison with the same fork. The capacity change from C_x' to C_x'' can be calculated corresponding with an exact frequency change of 500 cycles per second at a known frequency.

Keeping C_x at its C_x'' setting the frequency of G_1 is now reduced until the beat note is again reduced to 500 exactly and then the capacity of C_x is again increased to a calculable third value C_x''' by again raising the pitch of the heterodyne beat note to 1,000 cycles per second exactly.

In this way the variable condenser can be calibrated throughout its range with a number of 500 cycle increments of frequency and as an example a few points of an actual calibration are given below in Table 1.

G_1 first set to 100.2 kilocycles per second $= G_1'$.

The corresponding first setting of G_2 plus C_x gave the following:

$$f = 99.7 \text{ kc.}$$
$$C_T = C + c_s + C_x' = 255.5\ \mu\mu\text{F.}$$
$$\therefore \quad L = 9970\ \mu\text{H. (effective).}$$
$$C = 2.54 \times 10^6 f^{-2}\ \mu\mu\text{F.}$$
$$\frac{dC}{df} = -\,5.08 \times 10^6 f^{-3}\ \mu\mu\text{F./kc.}$$

factors of the overall inaccuracy will probably predominate.

The inaccuracy introduced by imperfect adjustment of frequency differences can be made negligible by comparing the heterodyne beat notes with a valve maintained tuning fork standardised to an accuracy of 1 part in 10,000 or higher, such as most laboratories now possess. But here again this refinement is unnecessary and the overall accuracy of measurement will probably not be limited by the fork inaccuracy if the latter is quite an ordinary hand pattern of 0.1 per cent. accuracy.

Assuming that the frequency of G_1 remains sensibly constant (except when altered intentionally) throughout the period of the test, the accuracy is limited by the accuracy with which the standard condenser C can be read and the accuracy with which the effective self-capacity C_s can be determined. For this reason therefore the value of C used should be as great as possible and an accurate method of self-capacity measurement employed.

TABLE 1.

G_1		Heterodyne Beat Note	G_2		$\frac{dC}{df}$	δC	C_x	
Setting.	kc.	kc.	Setting.	kc.	μμF./kc.	$= 0.5 \frac{dC}{df}$	μμF.	Setting.
G_1'	100.2	0.5	G_2'	99.7			0*	C_x'
					5.165	2.582		
G_1'	100.2	1.0	G_2''	99.2			2.582	C_x''
G_1''	99.7	0.5	G_2''	99.2				
					5.244	2.622		
G_1''	99.7	1.0	G_2'''	98.7			5.204	C_x'''
G_1'''	99.2	0.5	G_2'''	98.7				
					5.325	2.662		
G_1'''	99.2	1.0	G_2''''	98.2			7.866	C_x''''

* *Note.*—The number of significant figures of the values in this column must not be taken as an indication of the accuracy claimed.

Possible Errors.

It will be seen that $\frac{dC}{df}$ and consequently C_x is proportional to f^{-3}, but the accuracy of this term depends (almost wholly) upon one wavelength setting of the oscillator G_1. It will be obvious therefore that the same calibrated setting of G_1 should always be employed and, if this is done, a high degree of *frequency* accuracy is possible since frequent checks can then be made with facility even though the wavemeter is not of very good quality. A standardised quartz oscillator could, if necessary, be used for this single frequency, but is probably unnecessary as the percentage error of $\frac{dC}{df}$ is only three times that of f and other

Simplification of Method.

If one standardised frequency is used always for G_1, the values of $\frac{dC}{df}$ need be computed once only and will remain constant. This is important for it means that the capacity increments may be directly standardised. All that has to be done is to fix on the scale of the small variable condenser to be calibrated a false zero such that the correct 0.5 kilocycle heterodyne beat note is obtained with the single standardised frequency of G_1. At each 0.5 kc. interval throughout the calibration the direct capacities are then immediately known without any computation whatever.

In calibrating *very* small variable condensers the capacity increments will need to be less than those given in the tabulation and the frequency of G_1 is, of course, adjusted to meet these altered conditions, using a harmonic check, if necessary, to transfer the accuracy from the one standardised frequency.

A Useful Approximation.

For an accuracy of the order 2 per cent. and for very low capacities up to, say, 10 to 15 $\mu\mu$F., the calibration increments of capacity may be, as an approximation, taken as constant and may even be fixed at, say, 1.0 $\mu\mu$F intervals exactly by making a suitable corresponding adjustment of the initial frequency setting of G_1, which, for this accuracy, need not be a standardised point provided a wavemeter of reasonable quality is used. The fork also can be of quite ordinary quality.

As an example of this direct calibrating at 1.0 $\mu\mu$F. intervals, the following is given :

Initial setting $G_1' = 201.5$ kc.
,, ,, $G_2' = 201.0$ kc.
$L = 3160\ \mu$H. (effective)
Total capacity of $G_2 = C + c_s + C_x'$
$= 198\ \mu\mu$F.

$$C = 8.0 \times 10^6 f^{-2}\ \mu\mu\text{F.}$$

$$\frac{dC}{df} = -1.6 \times 10^7 f^{-3}\ \mu\mu\text{F./kc.}$$

The results of this calibration are given in Table 2.

The test is very quickly performed as no computation is needed and there are no constants to be remembered. Two initial conditions only must be adhered to; G_1' must be 201.5 kilocycles per second and the total capacity of G_2 at its initial setting must

TABLE 2.

G_1		Heterodyne Beat Note. kc.	G_2		$\frac{dC}{df}$ $\mu\mu$F./kc.	$\delta C = 0.5\frac{dC}{df}$	C_x		Error %
Setting.	kc.		Setting.	kc.			Setting.	$\mu\mu$F.	
G_1^{i}	201.5	0.5	G_2^{i}	201			C_x^{i}	0	0
					1.975	0.9875			
G_1^{i}	201.5	1.0	G_2^{ii}	200.5			C_x^{ii}	0.9875	+1.3%
G_1^{ii}	201	0.5	G_2^{ii}	200.5					
					1.995	0.9975			
G_1^{ii}	201	1.0	G_2^{iii}	200			C_x^{iii}	1.9850	+0.7%
G_1^{iii}	200.5	0.5	G_2^{iii}	200					
					2.005	1.0025			
G_1^{iii}	200.5	1.0	G_2^{iiii}	199.5			C_x^{iiii}	2.9875	+0.4%
G_1^{iiii}	200	0.5	G_2^{iiii}	199.5					
					2.025	1.0125			
G_1^{iiii}	200	1.0	G_2^{v}	199			C_x^{v}	4.0	0
G_1^{v}	199.5	0.5	G_2	199					
					2.040	1.020			
G_1^{v}	199.5	1.0	G_2^{vi}	198.5			C_x^{vi}	5.02	−0.4%
G_1^{vi}	199	0.5	G_2^{vi}	198.5					
					2.055	1.0275			
G_1^{vi}	199	1.0	G_2^{vii}	198			C_x^{vii}	6.0475	−0.8%
G_1^{vii}	198.5	0.5	G_2^{vii}	198					
					2.065	1.0325			
G_1^{vii}	198.5	1.0	G_2^{viii}	197.5			C_x^{viii}	7.08	−1.1%
G_1^{viii}	198	0.5	G_2^{viii}	197.5					
					2.082	1.041			
G_1^{viii}	198	1.0	G_2^{ix}	197			C_x^{ix}	8.12	−1.5%
G_1^{ix}	197.5	0.5	G_2^{ix}	197					
					2.10	1.05			
G_1^{ix}	197.5	1.0	G_2^{x}	196.5			C_x^{x}	9.17	−1.9%

be 198 $\mu\mu$F. This latter condition is easily complied with, after adjusting C_x' (the false zero of the condenser being calibrated) during the first self-capacity measurement by adjusting L to give the required 0.5 kc. heterodyne beat note with the 201.5 kc. setting of G_1.

Once adjusted L will remain unaltered for all tests and the self-capacity is not required to be measured again because C_x' can usually be adjusted to give the required beat note.

Measuring the False Zero C_x'.

If it is necessary to determine the value of the false zero C_x', the same method cannot, of course, be employed. A calibrated audio-frequency triode oscillator will be required to determine the pitch of the heterodyne beat note before and after completing the high potential lead from C to C_x when connecting the two condensers as Figs. 5 or 6. After finding the value of C_x', however, the calibration may be proceeded with by this constant frequency change method.

The Accurate Determination of Effective Self-capacity.

It has been seen in the foregoing notes that before the exact capacity increments corresponding with exact frequency increments can be computed, an accurate method of determining the effective self-capacity of the generator G_2 (as augmented by C_x') must be found.

The elementary method of plotting the square of the wavelength against added capacity is, of course, not sufficiently accurate for the purpose unless very precise wavelength standards are available.

The first method of experimentally obtaining, more accurately, the self-capacity of an inductance was that due to G. W. O. Howe.* This method may be employed when several inductances are available whose values are such as to give wavelength ranges slightly overlapping with the same variable condenser. For a given wavelength two variable condenser readings may be obtained, one near the zero of the condenser scale, where a knowledge of the self-capacity of the coil is essential, and a corresponding reading, obtained with a smaller inductance, near the maximum capacity end of the condenser scale, where the effect of the coil self-capacity is almost negligible. From two such readings the self-capacity in the first case (of the larger inductance) can be determined with fair accuracy as a large error in its assumed value when its effect is small causes only a small error in the calculated value when its effect is large.

Prof. Howe in his paper gives an example of the method using a simple resonant circuit wavemeter (with helium tube detector) loosely coupled to a "spark" source of oscillations—this was in the year 1912, it will be remembered.

In determining experimentally the self-capacity of a wavemeter the method should, if possible, as in that described above, be independent of wavelength in order to obtain accuracy. With the modern triode generator available, the best method of accomplishing this in the case of an oscillating triode wavemeter is one in which the necessary number of capacity readings are obtained by using harmonics of one constant source frequency only.

It will be remembered that the effective self-capacity C_s of the whole heterodyne wavemeter G_2 (Fig. 9) is required—a value as augmented by the "zero" value C_x' of the condenser being calibrated and by the leads by which the latter is connected to the calibrated variable condenser C. G_2 is therefore completely set up before commencing the test.

To commence the determination C is first set to a calibrated reading well towards the maximum capacity end of the scale and G_1 is adjusted nearly to resonance with G_2, the heterodyne beat note being adjusted to 1,000 cycles per second. G_1 then remains untouched throughout the test and assumed to be of constant frequency during this period.

Let this first capacity setting of C be C_1.

The wavemeter condenser is now adjusted to two other values C_2 and C_3, such that the corresponding wavelengths heterodyne with the second ($2f$) and third ($3f$) harmonics of G_1 respectively. Care must be taken to see that heterodyne beat notes of 2,000 and 3,000 per second are obtained in these two adjustments and that they are obtained on the same side of resonance as in heterodyning the fundamentals.

---

* "The Calibration of Wavemeters . . ." *Proc. Physical Soc. of London*, Vol. XXIV, Part V, 15th Aug., 1912.

Although the actual value of the wavelength is perhaps unknown, since C_1, C_2 and C_3 correspond with three wavelengths in the ratio λ, $\lambda/2$ and $\lambda/3$, the following expressions must hold :—

$$\frac{C_1 + C_s}{C_2 + C_s} = 4 \qquad \frac{C_1 + C_s}{C_3 + C_s} = 9$$

from which two values for self-capacity C_s can be found.

The Final Method of Determining C_s.

In good wavemeters, however, the total wavelength range covered at one sweep of the variable condenser rarely exceeds one octave, and this renders impossible the third harmonic adjustment or even, possibly, the second. In order to overcome this difficulty and in any case to obtain a larger number of values for C_s at all parts of the condenser scale the fundamental adjustment and even those of the lower harmonics may be omitted.

To do this the wavelength of G_1 is adjusted so that its fourth ($\lambda/4$) harmonic heterodynes with G_2 near the maximum end of the scale of the condenser C, the heterodyne beat note being adjusted to, say, 800 cycles per second. Let the capacity of C for this adjustment be C_4.

The capacity of C is now reduced to other values C_5, C_6, C_7 and C_8 corresponding with the heterodyning of the fifth, sixth, seventh and eighth harmonics of the original unaltered wavelength of G_1. Since at C_4 the heterodyne beat note between the fundamental of G_2 and the fourth harmonic of G_1 has been adjusted to 800 cycles per second, the beat notes corresponding with C_5, C_6, C_7 and C_8 must be adjusted to 1,000, 1,200, 1,400 and 1,600 cycles per second respectively so as to be in the same ratio as the actual frequencies of G_2. Care must, of course, be taken to make sure that all heterodyning takes place on the same side of resonance.

The following relations now hold :—

$$\frac{C_4 + C_s}{C_5 + C_s} = \left(\frac{5}{4}\right)^2$$

$$\frac{C_5 + C_s}{C_6 + C_s} = \left(\frac{6}{5}\right)^2$$

$$\frac{C_6 + C_s}{C_7 + C_s} = \left(\frac{7}{6}\right)^2$$

$$\frac{C_7 + C_s}{C_8 + C_s} = \left(\frac{8}{7}\right)^2$$

from which values for C_s can be computed for various parts of the scale of C.

As an example will be given the results of an experimental determination of the effective self-capacity of a heterodyne wavemeter (G_2) having a range of 3,500 to 8,000 metres with one sweep of its variable condenser.

G_1 was set to about 30,500 metres.

Although the range of G_2 was little over an octave, no fewer than five harmonic readings could be obtained. Each of these together with its appropriate heterodyne beat note and corresponding capacity reading is given in Table 3.

For the most accurate capacity measurements C should, if possible, have a value over 400 $\mu\mu$F. in order to reduce the uncertainty in the value of $C + C_s$.

TABLE 3.

Harmonic of G_1.	Appropriate Beat Note. cycles/sec.	Capacity Notation Previously Employed.	Capacity of C only. $\mu\mu$F.	Self-capacity C_s $\mu\mu$F.
$\lambda/4$	800	C_4	1211	102.9
$\lambda/5$	1000	C_5	738	103.1
$\lambda/6$	1200	C_6	481	103.2
$\lambda/7$	1400	C_7	326	104.5
$\lambda/8$	1600	C_8	225	

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

OBSERVATIONS ET TRAVAUX RÉCENTS SUR LA PROPAGATION DES ONDES ÉLECTROMAGNÉTIQUES (Observations and recent work on the Propagation of electromagnetic waves).—R. Mesny. (*L'Onde Élec.*, April, 1928, V. 7, pp. 130–155.)

The author's summary states that he passes in review the work done during the past two years on the question of propagation: the importance of the question of absorption, discussion on the nature of effective ions and on the mechanism of their formation, laboratory results on their influence on the electrical constants of gases, the influence of solar activity and of temperature. He then groups together the observations which agree with the present theories and those which appear in opposition. The field of research enlarges, but at the same time the points on which attention should be concentrated define themselves more clearly. He goes on to say that the paper does not deal with any new main theory, since the ideas of Eccles, taken up by Larmor and completed by Appleton and by Nichols and Schelling, are still to be found at the bottom of the theories; but their consequences have undergone rather profound modifications and certain details have been discussed and clinched more closely by various authors, whose results throw a more complete light on the phenomena. Among the observations not in agreement with the theories are the following: according to the theories, the rays useful for transmission should be those which make a smaller angle with earth in proportion as the wavelength is shorter. Whether the rays lose themselves by insufficient refraction (as Taylor considers) or by absorption in the ionising medium (as maintained by Eckersley), the rays with small zenith distance should not return to earth or should only return in a very small proportion. The good results produced by horizontal aerials do not fit in with these provisions, since their radiation to great zenith distances is very feeble; and Meissner's results in short-wave transmission from Berlin to Buenos Ayres are still more clearly in disagreement; good communication was obtained with a beam of 11 m. wavelength, directed almost vertically. The author concludes by summing-up some of the lines now demanding exploration: paying less attention to the idea of free electrons in an inactive space, the factors of ionisation and the nature of the ions require elucidation; new phenomena must perhaps be considered such as those which Nagaoka introduces into calculation and which Gutton and Clément deduce from experiments on the ionisation of gases; the earth's magnetic field does not play such a simple rôle as had been supposed; the Meissner results require an entirely new explanation; the true nature of the zones of silence and the attenuation of waves around 200 m. are further definite objects of research.

The abstract cannot even approximately cover the whole article, which deals with the work of numerous workers in addition to those already mentioned: including Lassen, Wegener, Watson, Pedersen, Breit and Tuve, Heising, Barnett, Ratcliffe, Bureau, Quäck, Howe, Pannecoek, Chapman, Cabannes and Dufay, Pickard, Austin, Van der Pol, Huber and Herath. A bibliography of 45 references is given.

THE POLARISATION OF RADIO WAVES.—J. Hollingworth. (*Proc. Royal Soc.*, 1st June, 1928, V. 119, Series A, pp. 444–464.)

The work described (part of the programme of the Radio Research Board) is being carried out by the author and Mr. Naismith to study by experimental methods the propagation of long radio waves. The present paper deals with waves longer than 10,000 m. and with distances between 400 and 1,000 km. (though results below 400 km., suggesting entirely different conditions of propagation, are indicated briefly). Present results show that: (*a*) during the hours of darkness, long wave intensities are moderately steady but show considerable abnormal polarisation; (*b*) at a time before sunrise corresponding to the sun's position of 7 degrees below the horizon at a point on the earth's surface mid-way between transmitter and receiver, an abrupt change lasting about 12 minutes occurs, during which the polarisation becomes much less; (*c*) a similar effect but with increase of polarisation occurs at sunset, its period being sometimes rather less definite and slightly longer; (*d*) at sunrise the value of the reflection coefficient which has remained at about its night value throughout period (*b*) falls gradually to its day value, which in summer is usually about 30 per cent. of its night value (but appears to be zero occasionally), and during this period the remainder of the abnormal polarisation disappears; (*e*) the evidence points to a much smaller change in equivalent height of the layer than has been assumed up to the present; it also suggests that a considerable proportion of the loss of energy in the indirect ray may occur below the actively refracting part of the layer rather than in it. The author also inclines to the idea that no real mechanical rising of the layer occurs, but merely a change in its electrical and physical state. The abrupt changes in the rotation of the plane of polarisation are shown in curves: the actual amount of rotation occurring varies daily, and a discussion of it is reserved for another paper.

STUDIES OF HIGH-FREQUENCY RADIO WAVE PROPAGATION.—A. Hoyt Taylor and L. C. Young. (*Proc. Inst. Rad. Eng.*, May, 1928, V. 16, pp. 561–578.)

Six questions of theoretical and practical interest which the authors set themselves to answer wholly or partially are given below, together with the summarised answer to each: (1) Why are signals usually received during the daylight hours in Washington from the Radio Corporation's group of stations at Rocky Point, operating on frequencies so high that Washington is well inside of the skip-distance zone? (2) Why do distant stations show what may be termed a normal time interval for round-the-world signals, whereas the Radio Corporation's group as measured in Washington invariably show time intervals notably shorter than the normal? These two questions are intimately related, and are therefore answered together as follows: It is shown that the signals in question do not violate the skip-distance law, nor are they signals formed by a scattering in the normal Heaviside layer, or by ground waves. They are signals thrown into the skip-distance area from a point or a number of points well outside that area, such that while the great circle distance between sender and receiver is only 420 kms., these signals travel from 2,900 km. to over 10,000 km. Tentative suggestions are made that these reflections occur at a heavily ionised region near the N. pole, or that they are scattered reflections thrown backwards from rough portions of the earth's surface in the first and second zones of reception following the skip-distance region—although it is admitted that this explanation when applied to the 10,000 km. results drives one to the Andes or Switzerland in order to get a suitable region.

Question (2) is automatically answered directly it is recognised that the first arriving signal is itself a form of echo signal of variable time-interval corresponding to the above-mentioned path-retardations.

The next question set is: (3) Can any further explanation be given of the fact that high-frequency signals usually show the worst fading at moderate distances and much less fading at the extreme limits of range? This is briefly answered by the suggestion that the "short-time" or nearby echo signals previously described may overlap and in continually shifting phase thus contribute to the fading at moderate distances. At much greater distances the nearby echoes would be much reduced in their effects.

Questions and Answers (4) and (5) deal with the influence of echo signals on various kinds of radio-communication, including facsimile telegraphy and television. The long-time echoes coming round the world can usually be taken care of by directive receiving systems, but this will probably not be the case for nearby echoes. Fortunately, we shall usually be mainly interested in telephony, facsimile transmission and television only over long distances, and it is suggested that this forms another argument for the reservation of such frequencies for long-distance work only. It is also suggested that the short-time echoes may be largely responsible for the widening of the angle of a beam to greater values than would be expected from an observation of its local performance.

Question (6) asks during what hours of the day and what seasons of the year different types of echo or "multiple" signals are to be expected, and this is answered (for round-the-world signals) by simple calculations based on the fact that such a signal must make most of its night transit in the summer hemisphere, and that if the great circle between two stations is such that this is not possible, round-the-world echoes will not occur. There is entirely too little information at hand to predict in the matter of short-time echoes, and it is urgently requested that observations on a quantitative basis be carried out in various parts of the world to demonstrate whether this is a phenomenon more or less peculiar to the locality of the authors' tests, or more general in its occurrence.

OSCILLOGRAPHIC OBSERVATIONS ON THE DIRECTION OF PROPAGATION AND FADING OF SHORT WAVES.—H. T. Friis. (*Proc. Inst. Rad. Eng.*, May, 1928, V. 16, pp. 658–665.)

The short-wave transmission path is generally but not always located in the vertical plane through the transmitting and receiving points. Direction-finding depends upon determining the direction of the wave at the receiving point; it does not give accurate results when the twilight zone is in the way of the wave path.

The angle between the earth and the direction of short-wave propagation varies continuously, and the changes in this angle are much larger than the changes in angle of propagation in the horizontal plane. The observations are consistent with the view that the fading is mainly caused by wave interference.

The above "author's summary" may be amplified as follows: the signals generally used were from the British beam station, GBK, 16 m. The method depends on the use of two spaced receivers at a distance of one-third or half a wavelength, each with a vertical aerial; beats are produced in each by a common local oscillator situated in the direction of the great circle, the line joining the spaced receivers being at right-angles to this line where direction in the horizontal place is being studied, and in line with it where the vertical plane is in question. The local signal does not vary or suffer from fading; therefore the beat note outputs of the two receivers can be combined to give cathode-ray oscillograph figures representing the phase difference and amplitude of the signal waves at the two receiving points. For complete results, the vertical and horizontal systems are in use simultaneously. The figures produced during fading have a rotating characteristic strikingly resembling that of figures based on the assumption of two waves of the same amplitude coming in at different angles.

ÜBER BEOBACHTUNGEN REGELMÄSSIGER SCHWUNDERSCHEINUNGEN IN ZUSAMMENHANG MIT SCHWANKUNGEN DER SENDEFREQUENZ BEI KURZEN WELLEN (Observations of regular fading effects connected with variations in transmitter frequency in short-wave transmission).—Eppen, Scheibe and Weight. (*Zeitschr. f. Hochf. Tech.*, May, 1928, V. 31, pp. 151–152.)

Tests in Germany on a crystal controlled transmitter ($\lambda = 37.65$ m.) showed very marked periodic fading varying, from day to day, between ½ and 2 periods per sec. The effects were very noticeable at distances from 3 to 17 km., and less regularly at greater distances.

No variation of wavelength was noticeable by ear with heterodyne reception, and local measurements showed no variation in transmitter aerial-current comparable with the effects noted (which caused aural signals to vary from good to inaudible). It was therefore concluded that the fading was caused by interference between two rays (arriving by different paths) giving maxima at certain receiving points and minima at others: and that these maxima and minima were periodically shifted by periodic small changes in the transmitted wavelength. To verify this, the heterodyned continuous dash (at a distance of 17 km.) was recorded by an oscillograph and showed regular pulsations of amplitude of 4.1 sec. duration. A second oscillograph loop simultaneously recorded the heterodyned signals, with a buzzer frequency of 1,000 p.s. superimposed. Variations in wavelength caused a varying number of beats per second, and these changes of beat-frequency synchronise with the amplitude changes. It was afterwards discovered that the changes of amplitude coincided with fluctuations in the filament-current of the crystal controlled first-stage valve.

Woods and Wireless.—R. H. Barfield. (Letter to *Nature*, 9th June, 1928, V. 121, p. 908.)

The writer refers to Dr. Rolf's letter (*Nature*, 7th April, 1928; see Abstracts for June) and while agreeing that the capacity effect should be considered as well as the conductivity effect, doubts whether the simple adaptation of Sommerfeld's theory (suggested by Rolf) can be correct, the constants being for an isotropic medium and therefore applying only to the vertical axis of a tree. He points out that if we increase the conductivity of a tree we clearly increase the energy absorbed and hence the attenuation, whereas by Rolf's method the opposite is the case. He also doubts whether the effect of negative damping at Daventry was caused by trees, as this region is one of comparatively few trees, and the departure of the attenuation from its ideal value (assuming a bare surface) has been found to be small. The explanation, however, should not be abandoned without further investigation.

Propagation des Ondes Courtes Autour de la Terre (Propagation of Short Waves round the Earth).—J. Reyt. (*T.S.F. Moderne*, Jan., Feb. and March, 1928, V. 9, pp. 1–12, 73–86, 150–164.)

A review of the present knowledge and ideas. The writer particularly examines the variation of skip-distance with the wavelength and with the seasons, and finishes by showing how the present knowledge can be applied in choosing wavelengths, and other conditions, for a given radio service.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

A Note on Corona at High Humidity.—A. W. Simon. (*Proc. National Acad. Sciences, Washington*, March, 1928, V. 14, quoted in *Nature*, 2 June, 1928, p. 891.)

A description of an effect noticed on an arrangement normally giving heavy visual corona. On very wet days no corona was visible, the current flowing was much reduced, and intermittent sparking occurred, possibly due to reduced mobility of the negative ions.

Relations Entre la Propagation des Ondes Électromagnétiques, l'Activité Solaire et l'État Atmosphérique (Relations between the propagation of electromagnetic waves, solar activity and the condition of the atmosphere).—A. Nodon. (*L'Onde Élec.*, April, 1928, pp. 156–161.)

Solar disturbances, at the periods of evolution of diametrically opposed conjugate foci, were particularly intense during the summer of 1927, and the author records in graphical form, and discusses, his observations in the W. Pyrenees from the end of May to the end of September. The diagram shows, one above the other and plotted on the same time scale, the various effects in question: transient foci, lasting foci, passage of these across the sun; electro-magnetic oscillations; propagation of waves (" good reception " above the zero line, " bad reception " below); general state of the atmosphere (deduced from information at distances by wireless and from the press); and local atmospheric conditions.

Good reception seems to occur as the lasting active foci pass to the edges of the sun's disc, but this effect is sometimes obscured by the appearance of transient foci. The curve for " general state of the atmosphere " corresponds very closely with that for " good and bad reception." Magnetometer and electrometer results (not represented graphically) showed continuous disturbances, day and night, throughout the long period of activity; two short intervals of rest coincided with two marked improvements on the curves, and quiescence entered abruptly when the two very active foci disappeared. General atmospheric disturbances disappeared at the same time, and radio reception became normal. The curves of " local atmospheric conditions " differ greatly from the others; the only agreements noticeable are at the dates of the most violent disturbances, which thus seem to dominate the local actions. The writer says: " The new observations seem to confirm this hypothesis " (the influence on radio propagation of ultra-radiations of origin extra-terrestial and more particularly solar); " the effects of ionisation in the upper atmosphere and at the ground surface being probably attributable to the Compton Effect, giving birth to radiations of a much greater length than that of the ultra-radiations which provoke them."

High Voltages from the Atmosphere.—(*Elec. Review*, 8 June, 1928, V. 102, p. 1006.)

A paragraph referring to the experiments now in progress near Lugano.

During storms, spark discharges 15 feet long at the rate of about one per second have been obtained for half an hour on end. It is hoped finally to attain 30 million volts.

The Sun's Outer Atmosphere.—E. A. Milne. (*Nature*, 9 and 16 June, 1928, V. 121.)

OBSERVATIONS ON ATMOSPHERIC ELECTRICAL CONDUCTIVITY IN CONNECTION WITH THE SOLAR ECLIPSE OF JUNE 29, 1927.—Nolan and O'Brolchain. (*Proc. Roy. Irish Acad.*, Jan. 1928, pp. 1–17.)

AN AUTOMATIC RECORDER FOR MEASURING THE STRENGTH OF RADIO SIGNALS AND ATMOSPHERIC DISTURBANCES.—(*See under* "Subsidiary Apparatus.")

PROPERTIES OF CIRCUITS.

ON BANKS OF PARALLELED VALVES FEEDING RESISTIVE LOADS WITHOUT DISTORTING THE WAVE FORM.—W. Baggally. (*E.W. & W.E.*, June, 1928, V. 5, pp. 315–321.)

DAMPING DUE TO GRID CURRENT IN THE CASE OF A VALVE OSCILLATOR.—M. Reed. (*E.W. & W.E.*, June, 1928, V. 5, pp. 322–324.)

REACTANCE AND ADMITTANCE CURVES: APPLIED TO TUNED CIRCUITS WITH AND WITHOUT RESISTANCE.—L. T. Bird. (*E.W. & W.E.*, June, 1928, V. 5, pp. 327–334.)

TRANSMISSION.

"BEAM" WIRELESS TELEGRAPHY.—N. Wells. (*Elec. Review*, 25th May and 1st June, 1928, V. 102, pp. 898–902 and 940–943.)

A straightforward explanation of the theory underlying the Franklin aerial system used in the Marconi beam transmitters; illustrated by photographs, diagrams and curves. The June article is an appendix to the first, describing the graphical construction of polar curves.

LA THÉORIE DU RAYONNEMENT DE LA BEAM ANTENNE (The Theory of the Radiation from a Beam Aerial).—G. F. d'Ailly. (*Q.S.T. Français*, June, 1928, No. 51, pp. 14–19.)

The general theory of the beam aerial with its reflector is outlined, and the rest of the article neglects the reflector in order to work out simply the mathematics of the aerial itself. The next article will show how the reflector is introduced.

DIE RUNDFUNKSENDER DER WELT (The World's Broadcasting Stations).—(*Rad. f. Alle*, June, 1928, V. 7, pp. 251–252.)

A complete table arranged in increasing order of wavelengths. The corresponding "kilohertz" (kilocycles per sec.) and the power are also given in all but a few cases.

THE DISTRIBUTION OF CURRENT IN A TRANSMITTING ANTENNA.—R. M. Wilmotte. (*Journ. I.E.E.*, June, 1928, V. 66, pp. 617–627.)

It is well known that, owing to the proximity of the ground, the effective capacity per unit length at the lower end of an aerial will be greater than that at the upper end; moreover, there are end-effects which give the appearance of producing a larger capacity near the ends than in the central portions. For the purpose of calculating polar radiation diagrams, radiation resistances and effective heights, it is very important to know whether the assumption of a sinusoidal distribution of current (neglecting the above effects) is sufficiently accurate, and what errors such an assumption is likely to produce. The writer describes experiments in which the current distribution of a straight vertical aerial (and later of variously shaped aerials) was found by placing ammeters at various points along the aerial and reading them by means of a telescope. Results showed remarkably good agreement with the sinusoidal assumption, over the whole range of wavelengths (15 m. to 800 m.). The highest frequency was nearly three times the nat. frequency of the aerial. The experiments were extended to test the effect of certain changes, and the results are given. The simple theory for the Current Distribution is given in an appendix, and the paper itself includes a theoretical investigation of the problem without the assumption of uniformly distributed constants. The investigation was carried out as part of the programme of the Radio Research Board.

RECENT DEVELOPMENTS IN LOW POWER AND BROADCASTING SETS.—I. F. Byrnes. (*Proc. Inst. Rad. Eng.*, May, 1928, V. 16, pp. 614–651.)

Various types of radio transmitting equipments are described and illustrated, ranging in output from 200 to 2,000 watts. The application of master-oscillator power-amplifier circuits for low and medium frequency transmitters is explained, and the uses of quartz crystal control for high frequency and broadcast transmitters are described. A full schematic circuit-diagram of a 1 kW. broadcast transmitter is shown. A brief explanation is also given of the equi-signal system of radio beacon transmission, which promises to become an important aid in the navigation of aircraft. This beacon transmitter uses as aerials two large loops at right angles, to which it is coupled by a modified goniometer whose rotating primary consists of two coils. These rotor-coils are alternately connected to the radio transmitter by an automatic relay, and by suitable adjustment of the angle between them, the patterns of the two loops are made to overlap. In this overlapping zone, what is known as an equi-signal area is maintained, and by rotating the whole rotor the course set by this equi-signal area can be altered. Interlocking signals are produced by the automatic relay, *e.g.*, the letter *N* on one rotor-coil interlocking with the letter *A* on the other, so that the receiving operator flying in the equi-signal zone hears a series of uniform dashes; whereas if he deviates from the course set, he hears *N* or *A* predominating. The only example given of such a beacon-transmitter uses wavelengths of the order of 1,000 metres.

SHORT-WAVE AERIAL SYSTEMS: AN ELEMENTARY THEORY OF THE TRANSMISSION OF HIGH-FREQUENCY ENERGY ALONG THE FEEDERS.—E. Green. (*E.W. & W.E.*, June, 1928, V. 5, pp. 304–311.)

Étude d'un Générateur à Ondes Courtes (Study of a Short-wave Generator).—F. Flaud. (*L'Onde Élect.*, May, 1928, V. 7, pp. 196–205.)

The particular arrangement obtained by the author, which he considers to be so stable and free from difficulties that it should lend itself to the production of shorter waves than have hitherto been obtained by valve methods outside the laboratory, is a modification of the Hartley method. The wavelength used by the writer is of the order of 30 metres.

The Design of Variable Condensers for High Voltage Operations.—B. E. Smith. (*Q.S.T.*, March, 1928, V. 15, pp. 49–51, 66 and 68.)

An article on the design of continuously variable condensers for valve-transmitters.

RECEPTION.

Drei Einröhren - Experimentier - Empfänger (Three One-Valve Experimental Receivers). Günther and Schreiber. (*Rad. f. Alle*, June, 1928, V. 7, pp. 257–272.)

Constructional details are given, and a great number of circuit-diagrams show how a very large variety of circuits, all using only one three-electrode valve, can be employed. These vary from simple circuits, such as those of the Audion with or without reaction, to those of Reinartz, Flewelling (" pendulum ") and the Super-regenerative system.

Die Verwendung von Siebkreisen (The Use of Filter Circuits).—W. Nestel. (*Rad. f. Alle*, June, 1928, V. 7, pp. 241–243.)

The particular circuit dealt with here is a wave-stopper or trap for cutting out the local station to get distant reception.

Über den Netzanschluss von Widerstandverstärkern (Mains Supply for Resistance Amplifiers).—H. Kröncke. (*Rad. f. Alle*, June, 1928, V. 7, pp. 248–250.)

A.C. mains are here meant; the circuit is due to v. Ardenne and includes a triple receiving valve.

A.C. Tubes Versus Series Filament Operation.—W. P. Lear. (*Rad. Engineering*, June, 1928, V. 8, pp. 45–49.)

The writer recommends the use of rectified A.C. through filaments in series, as superior to the recently popular use of A.C. valves. Reaction with the latter arrangement leads to trouble which is absent in the former.

The Theory of " Push-Pull."—N. W. McLachlan. (*Wireless World*, 13th, June, 1928, V. 22, pp. 629–634).

The author reviews the position of this method which is now coming into vogue (although invented 13 years ago) and indicates practical points essential for proper performance, *e.g.*, the necessity for " matched " valves.

Discussion on the Distortionless Reception of a Modulated Wave and its Relation to Selectivity.—(*Proc. Inst. Rad. Eng.*, May, 1928, V. 16, pp. 671–673.)

A further contribution to the discussion on Dr. Vreeland's paper (see Abstracts for May and June.)

The Apparent Demodulation of a Weak Station by a Stronger One.—R. T. Beatty. (*E.W. & W.E.*, June, 1928, V. 5, pp. 300–303.)

Modern Naval Receivers (Long-Range Sets with Screened Grid H.F. Amplifiers).—(*Wireless World*, 30th May, 1928, V. 22, pp. 566–569.)

An illustrated description of some receivers designed by the Marconi Company in collaboration with British naval experts. An interesting point is a new modification of " gang-control " which is here used for four separate variable condensers.

Wireless at the Paris Fair (Some Interesting Exhibits Described).—(*Wireless World*, 30th May, 1928, V. 22, pp. 581–583.)

An illustrated description of several French broadcast receivers, most of which are superheterodynes and are distinguished by ingenious methods for calibrated adjustment.

American Sets of To-day: Progress in Radio Receiver Design during the Last Year (Illustrated).—(*Wireless World*, 27th June, 1928, V. 22, pp. 685–688.)

Tuned Radio-Frequency Amplifiers.—R. S. Glasgow. (*Journ. A.I.E.E.*, May, 1928, V. 47, pp. 327–331.)

A simplified method of calculating the performance of a tuned amplifier circuit is given and the effect of the various circuit constants on the characteristics is shown. The predicted results are found to check experimental observation quite closely. The factors affecting the stability are pointed out, and typical methods (" bridge-type " circuits) for suppressing undesired oscillations are given, together with the principles involved.

VALVES AND THERMIONICS.

Étude Expérimentale et Théorique des Lampes à deux Électrodes (Experimental and theoretical study of two-electrode valves).—Y. Doucet. (*Q.S.T. Français*, June, 1928, No. 51, pp. 31–39.)

The phenomena of the two-electrode valve are examined in detail by experimental and mathematical methods: thus the laws of Richardson, Langmuir and Maxwell (" distribution of velocities") the Saturation Curve and the Influence of the gaseous medium are all considered.

Short Undamped Electric Waves.—K. Kohl. (*Ann. der Physik*, 18th January, 1928, pp. 1–62.)

Valve methods of producing waves of length

30–60 cms. A positive potential of the order of 600 volts was used for the shortest waves and in certain cases the oscillatory circuit was sealed inside the valve.

THE EFFECT OF INITIAL VELOCITY OF ELECTRONS UPON THE ANODE CURRENT OF A VACUUM TUBE.—N. Kato. (*Phys. Review*, May, 1928, V. 31, pp. 858–861.)

By eliminating the other causes of deviation, the author measured the degree of deviation of the current-voltage curve from the three-halves power law (derived from the space-charge equation). He finds the effective initial velocity of electrons to vary from about 0.5 v. at 2,250 degrees to 4 v. at 3,000 degrees. The velocity seems to be independent of the dimensions of the electrodes.

SUR LA RÉALISATION ET LE FONCTIONNEMENT D'UN NOUVEL OSCILLATEUR À ONDES TRÈS COURTES (The construction and method of working of a new oscillator for very short waves).—E. Pierret. (*Comptes Rendus*. 11th June, 1928, V. 186, pp. 1601–1603.)

Further reports on the production of stable oscillations (wavelength about 16 cms.) mentioned in July Abstracts; this time only one valve is used, as it was found that the two valves previously required had to be very carefully "paired." A mathematical explanation of the method is given.

USE OF AN OSCILLOGRAPH FOR RECORDING VACUUM-TUBE CHARACTERISTICS.—W. A. Schneider. (*Proc. Inst. Rad. Eng.*, May, 1928, V. 16, pp. 674–680.)

This paper describes the method involved and the results obtained. The main requirement is an alternating voltage of fairly pure wave-form with as few harmonics as possible. The "dynatron" action is shown very clearly when large alternating E.M.F.'s are applied to the grid. Static and dynamic characteristics can also be recorded quite easily. The author particularly used the method for the study of the behaviour of valves when large positive potentials are applied to the grid, *i.e.*, when the valve acts as a negative resistance.

EINIGE ÜBERLEGUNGEN ZUR PHYSIKALISCHEN BEDEUTUNG DER GLÜHELEKTRONENEMISSION (Some considerations as to the physical meaning of thermionic emission).—v. Hippel. (*Zeitschr. f. Phys.*, No. 9/10, 1928, V.46, pp. 716–724.)

The author maintains that the cause of emission is temperature-ionisation by electron impact, and not volatilisation as is stated by Richardson and Dushman. He arrived at equations for the emission exactly similar to those of the workers named, except that his constants have different physical meanings.

DETECTION BY GRID RECTIFICATION WITH THE HIGH-VACUUM TRIODE.—S. Ballantine. (*Proc. Inst. Rad. Eng.*, May, 1928, V. 16, pp. 593–613.)

The theory of detection of small signals by grid rectification with the high-vacuum triode of the 201A type is briefly discussed by means of the mathematical method of Carson. Special attention is given to the grid-leak, grid-condenser arrangement. The relations between the non-linear distortion and the degree of modulation, and between the frequency distortion and the grid impedances, are discussed. A convenient method is described for ascertaining experimentally the frequency distortion in detection, illustrated by means of results in a typical case; this distortion is compared with that due to resonance in the H.F. amplifier circuits. A method of securing efficient grid-rectification in the super-heterodyne system is described. The detection coefficients for the 200A valve are given in an appendix: this valve appears to contain alkali vapour derived from a capsule contained in a small hemi-spherical boss welded to the plate.

PLATINUM ALLOYS IN THERMIONIC VALVES. (*Nature*, 2nd June, 1928, V. 121, p. 884, summarised from Bell Lab. Record for April.)

For thermionic valve repeaters, J. E. Harris describes the manufacture of platinum alloys which are used because there is no chemical action between them and the barium and strontium oxides with which they have to be coated. It is found that chemical reaction weakens the thermionic activity of the coating when metals such as tungsten are used.

SCREENED-GRID VALVES: INFORMAL DISCUSSION AT I.E.E. WIRELESS SECTION. (*E.W. & W.E.*, June, 1928, V. 5, pp. 335–338.)

L'INFLUENCE DES ÉMISSIONS SECONDAIRES DES MÉTAUX SUR LE FONCTIONNEMENT DES LAMPES À TROIS ÉLECTRODES (The influence of secondary emission from metals on the working of three-electrode valves).—H. Le Boiteux. (*Rev. Gén. de l Élec.*, 2nd June, 1928, V. 23, pp. 939–946, and 9th June, pp. 984–992.)

The secondary emissions studied by Farnsworth and Langmuir are here used to explain certain valve phenomena which have obtruded themselves specially since valves have been employed to generate very short waves: such as abnormal heating of the glass, etc., parasitic waves (always shorter), impossibility of producing a clear heterodyne beat-note, and the production of unstable conditions with the liberation of energy quite out of proportion to the normal power of the valve. Mathematical development leads to a formula for the calculation of the efficiency of an oscillator-valve, and the author shows that this agrees admirably with experimental results both for small and large (20 kW.) valves. In the second part, the author deals with: (*a*) conditions for working without disturbance by secondary emission effects; (*b*) zone of period affected; (*c*) consequences of the emission; (*d*) form of secondary current during the oscillation; (*e*) possibility of electrons returning to cathode; etc., etc.

DIE STROMVERTEILUNG IN DREIELECTRODENRÖHREN . . . (Current distribution in three-electrode valves . . .).—H. Lange. (*Zeitschr. f. Hochf. Tech.*, May, 1928, V. 31, pp. 133–140.)

Continuation of the paper abstracted in July number. The present part is divided into the following: *C*, The electron paths: lines of constant potential: lines of constant action: influence of thickness of grid: experimental verification (curves taken with three valves with very different types of grid are shown, and the slight discrepancies in shape between observed and calculated curves are explained). Having thus laid down the theoretical foundations of Current Distribution, the author investigates how it is affected by higher filament-temperatures, by the appearance of Space Charges, and (following the removal of the rotating commutator used in the previous tests) by the voltage-drop in the filament. The present instalment deals with these points in Section D; the completion of the whole paper is to follow next month.

ÜBER DIE KOMPENSATION DER SCHÄDLICHEN KAPAZITATEN . . . (The Compensation for undesired capacities . . .).—Ardenne and Stoff. (*Zeitschr. f. Hochf. Tech.*, May, 1928, V. 31, pp. 152–157.)

Continuation of the paper abstracted in July issue: C2. Valve circuits with aperiodic couplings: compensation by interconnection of alternate valves (Leithaüser-Heegner): compensation by double-grid valves: compensation by amplifiers in opposition. Practical work: low-frequency opposition of amplifiers: high-frequency opposition of amplifiers.

DIRECTIONAL WIRELESS.

APPARENT NIGHT VARIATIONS WITH CROSSED-COIL RADIO BEACONS.—H. Pratt. (*Proc. Inst. Rad. Eng.*, May, 1928, V. 16, pp. 653–657.)

The equi-signal zone system of aircraft directing, by "Crossed-coil" Radio beacons, is described in an article abstracted elsewhere (see these Abstracts, "Recent Developments in Low Power and Broadcasting Sets," I. F. Byrnes, under "Transmission"). The present article again outlines the system and its advantages, but is chiefly devoted to unfortunate defects which became evident in the system when used for night-flying. These effects were a combination of apparent wave-direction shifts and fading, and resulted in the beacon being difficult to use between 25 and 50 miles, of questionable value at about 100 miles, and of no use at all at 125 miles. The shifting of the zone was gradual, so that at first one would be inclined to think it due to the movement of the aircraft itself. The topography of the country between beacon and aircraft exerted a considerable influence on the extent of the variation. Exceptional variations in shift over an arc as great as 100 degrees in Azimuth were noted, but in general the change was confined to within possibly 25 degrees. Beyond 15 miles the fading of the general level of signal received was very severe during flight over mountains. Observations on the ground, at a distance of 134 miles, gave less pronounced shifting than in the air. Further ground tests, in mountainous country at distances of 18 to 53 miles, seemed to show that fading played only a minor part in the phenomenon, but a variation in the direction of the arriving field was observed as large as 30 degrees over a ten minute interval. On the other hand, on one particular night-flight signals from a second beacon, near which there were no marked mountain ranges, showed no shifting whatever. The wavelength employed throughout was about 1,000 m., modulated at 500 cycles. Further investigation is urgently needed.

DIRECTIONAL PROPERTIES OF TRANSMITTING AND RECEIVING ANTENNA.—Clapp and Chinn. (*Q.S.T.*, March, 1928, V. 15, pp. 17–30.)

Methods of obtaining a beam effect for private stations transmitting or receiving on short wavelengths (40 m. is mentioned as an upper limit above which mechanical difficulties become serious) are thoroughly gone into in this article.

THE EQUI-SIGNAL SYSTEM OF RADIO BEACON FOR AIRCRAFT TO SET COURSES BY PROJECTING EQUI-SIGNAL ZONES OF INTERLOCKED SIGNALS. (*See* Abstract under "Transmission," entitled "Recent Developments in Low Power and Broadcasting Sets.")

OSCILLOGRAPHIC OBSERVATIONS ON THE DIRECTION OF PROPAGATION AND FADING OF SHORT WAVES.—H. T. Friis. (*See* under "Propagation of Waves.")

MEASUREMENTS AND STANDARDS.

THE EQUIVALENT INDUCTANCE AND CAPACITY OF AN AERIAL.—(Editorial.) (*E.W. & W.E.*, June, 1928, V. 5, pp. 297–299.)

GRAPHICAL COMPUTATION.—M. H. Ashworth. (*E.W. & W.E.*, June, 1928, V. 5, pp. 311–314.)

SUBSTANDARD WAVEMETER DESIGN.—W. H. F. Griffiths. (*E.W. & W.E.*, June, 1928, V. 5, pp. 324–326.)

ELECTRICAL MEASURING INSTRUMENTS OTHER THAN INTEGRATING METERS.—C. V. Drysdale. (*Journ. I.E.E.*, June, 1928, V. 66, pp. 596–616.)

A comprehensive "review of progress" dealing first with Commercial Indicating and Recording Instruments, then with Laboratory Instruments, and finally with Sensitive Controlling Devices. The latest developments in all these fields are described. Among those of special interest for radio work are the "signal strength meter" (accurate to about 10 per cent.); the Moll thermo-converter (in which a long straight heating wire of about 16 ohms resistance is plaited through a series of 50 thermo-junctions; a current of 16 mA produces a full deflection of a millivoltmeter, but the heating wire can carry 300 mA without injury) and the Moll wattmeter for direct measurements of H.F. power down to a fraction of a watt; photo-electric cells; cathode ray oscillographs; the Dye standard multivibrator wavemeter; and many others.

A NEW AMMETER FOR MEASURING VERY HIGH FREQUENCY CURRENTS.—(*Electrician*, 25th May, 1928, V. 100, p. 576.)

A description of Mr. E. B. Moullin's new ammeter exhibited at the Royal Society Conversazione. It is suitable for currents of very high frequency such as are used in "beam" systems, and avoids the various sources of error common to the usual thermal methods. It depends on the repulsive force between two long parallel cylinders traversed by the high frequency current to be measured, one cylinder being movable (parallel to itself) against an elastic constraint; the movement is observed by a microscope. The geometrical form of the components enables the frequency-correction to be calculated exactly, and there is nothing to "burn out." The particular instrument gives a scale deflection of a hundred divisions for a current of 1.2A, and the power absorbed is about 0.25 W.

LEISTUNGS- UND STRAHLUNGSMESSUNGEN AN FLUGZEUG- UND BODENSTATIONEN (Power and Radiation Measurements in Aeroplane and Land Stations).—Eisner, Fassbender and Kurlbaum. (*Zeitschr. f. Hochf. Tech.*, May, 1928, V. 31, pp. 141–151.)

The second and final part of this paper (see Abstracts for July) comprising II. Radiation measurements in Aerials: description of method (Anders' process): results of tests. The chief conclusions drawn are that: (*a*) the usual trailing aerial has not, as often supposed, a specially good radiation; (*b*) the international aircraft wavelength of 900 m. gives a comparatively poor efficiency; (*c*) the height of the aircraft, at short distances (*i.e.*, to the limit of the short-range zone), has very little effect on the strength of the field produced; (*d*) the polar curve of the trailing aerial is circular, not irregular as had been supposed; (*e*) the radiation varies by nearly straight line law with its length; (*f*) fixed aeroplane aerials of practical form have a radiation about 10 per cent. of that of a trailing aerial 70 m. long.

CONTINUOUS READING OF VARYING POTENTIALS BY MEANS OF THERMIONIC VALVES.—D. T. Harris. (*Journ. Sci. Instruments*, May, 1928, V. 5, pp. 161–166.)

An assembly of apparatus with steady zero-reading is described. Primarily designed for following changes in bio-electric potential differences, it is suitable for many other purposes, *e.g.*, for measuring photo-electric potentials. The drift in the zero is usually less than the equivalent of a rate of change of grid potential of one milli-volt per hour, and can be still further reduced.

LABORATORY MEASUREMENT OF CAPACITY, POWER FACTOR, DIELECTRIC CONSTANT, INDUCTANCE AND RESISTANCE, BY USE OF THE SERIES RESISTANCE BRIDGE.—C. L. Lyons. (*Journ. Sci. Instruments*, May, 1928, V. 5, pp. 155–160.)

The ordinary bridge is often hampered by the fact that stray capacities are frequently of the same order of magnitude as those under measurement. This paper (of which the present article is the first part) describes a more satisfactory form (modified from Wiens' Series Resistance Bridge) incorporating the complete shielding of its elements: it is made by the General Radio Co. (America). Auxiliary equipment is surveyed, including items such as sources of A.C. suitable in wave-form and of fixed frequency (Vreeland Oscillator, Tuning-fork-controlled oscillator); auxiliary valve amplifier of tuned audio-frequency type; and the general operations, formulæ, etc., are given.

SUBSIDIARY APPARATUS AND MATERIALS.

AN AUTOMATIC RECORDER FOR MEASURING THE STRENGTH OF RADIO SIGNALS AND ATMOSPHERIC DISTURBANCES.—E. B. Judson. (*Proc. Inst. Rad. Eng.*, May, 1928, V. 16, pp. 666–670.)

The receiver, amplifiers, rectifier and recorder are switched on by relays controlled by a clock and arranged so that for different five-minute periods during the hour the strength of several stations may be recorded. Only audio-frequency amplification is used, for greater constancy of sensitivity. A Cambridge-Paul Thread Recorder is employed. Keeping filament-currents and plate-voltages constant, the system retains its calibration within 10 per cent. over periods of several months. Typical curves of the variations in signals and atmospheric disturbances are given.

THE KLYDONOGRAPH.—J. Fallow. (*Rev. Gén. de l'Elec.*, 2nd June, 1928, V. 23, pp. 958–961.)

This portion of a long article, dealing with the probable form of the extra high tensions induced in aerial lines by thunderstorms, etc., describes the instrument in question, which permanently records, classifies, and measures voltages even of ephemeral duration. The method of record is by the effect of the discharge on a photographic plate or film, producing figures resembling those of Lichtenberg.

MECHANICAL PRODUCTION OF SHORT FLASHES OF LIGHT.—J. W. Beams. (*Nature*, 2nd June, 1928, V. 121, p. 863.)

A method of obtaining a train of very rapid flashes of light, of duration 10^{-8} second or less, for stroboscopic study of phenomena which occur in a very short interval of time.

INSTRUCTION ON THE MAKING OF POTASSIUM HYDRIDE PHOTO-ELECTRIC CELLS.—W. B. Nottingham. (*Journ. Franklin Inst.*, May, 1928, V. 206, pp. 637–648.)

A full description of the process developed at the Franklin Institute for making cells of high sensitivity.

A PORTABLE CATHODE RAY OSCILLOGRAPH.—(*E.T.Z.*, 7th June, 1928, V. 49, p. 868.)

A new G.E.C. production, the whole equipment being distributed between two vans, one of which forms a dark room.

EINE NEUERUNG AM KATHODENOSZILLOGRAPHEN (A new form of Cathode-ray Oscillograph).—P. Selényi. (*Zeitschr. f. Physik*, V. 47, 1928. p. 895.)

The passage of the Cathode-ray is marked, in this new method, by powder scattered on the flat glass wall and affected by the negative charge left by the ray. Positive ions (which would tend to neutralise this charge) are kept away by an auxiliary electrode.

FOLGESCHALTUNGEN FÜR KATHODENSTRAHL-OSZILLOGRAPHEN (Sequence-switching for Cathode-ray Oscillographs).—(*E.T.Z.*, 24th May, 1928, V. 49, pp. 798–799.)

An article giving the collated methods of various workers, among whom are Dufour, Rogowski and Flegler, Harrington and Opsahl, and Gábor; the methods ranging from the quaint arrangements of ring-formed electrodes traversed by bullets, through the mechanical methods of contact-discs and commutators, to the purely electrical methods, two of these using spark-gaps, one (Rogowski) using a 3-electrode valve and a condenser charged through a resistance, while one (Gábor) uses two 3-electrode valves.

NOTES ON THE DESIGN OF IRON-CORE REACTANCES WHICH CARRY DIRECT CURRENT.—D. E. Replogle. (*Q.S.T.*, April, 1928, V. 15, pp. 23–27.)

Curves and calculations for the design of filter chokes carrying a large amount of D.C. with a superimposed A.C. ripple.

AUTOMATIC VOLTAGE-STABILISER FOR APPARATUS FED FROM A.C. MAINS.—Soulié. (*Comptes Rendus*, 4th June, 1928, V. 186, pp. 1428–1530.)

A circuit consisting of a condenser and a solenoid with a laminated iron core which can displace itself along the vertical axis of the solenoid, its movement being damped by a disc in oil.

When the supply voltage varies from 90 to 112 volts, the voltage across the condenser (*i.e.*, the working voltage) varies only from 96.5 to 96 volts. With a better model of solenoid, even better results were obtained, and the filament of a Coolidge tube was kept practically constant in temperature although the supply voltage varied between 105 and 140 v. The A.C. frequency was 50 per sec.

SAFETY AND THE MAINS: PRECAUTIONS TO BE TAKEN WHEN USING BATTERY ELIMINATORS.—P. R. Coursey. (*Wireless World*, 20th June, 1928, V. 22, pp. 657–660.)

METAL RECTIFIERS.—(*The Engineer*, 22nd June, 1928, V. 145, p. 684.)

An illustrated article on the copper-disc rectifiers made, in various sizes and for various purposes, by the Westinghouse Company. (*Cf.* article by C. Chouquet, July Abstracts, under "Subsidiary Apparatus.")

THE SULPHIDE RECTIFIER: AN EXPLANATION OF ITS FUNCTIONING AND ITS APPLICATION TO RADIO AND INDUSTRIAL USES.—H. Shoemaker. (*Rad. Engineering*, June, 1928, V. 8, pp. 35–38.)

A full description of the "Elkon" metal-disc rectifier in which the copper disc has a sulphide deposit on one side and the separating discs (which also act as cooling fins) are of aluminium. For battery-charging purposes, a life of 5,000 hours may be expected.

PAPER VERSUS MICA CONDENSERS IN RADIO FREQUENCY CIRCUITS.—J. G. Uzmann. (*Rad. Engineering*, June, 1928, V. 8, p. 53.)

A note on the comparative power-factors of paper and mica condensers, leading to the conclusion that the growing tendency to substitute small paper condensers for the more expensive mica ones is completely unsound, so far as resonant circuits are concerned.

LE PROBLÈME DU FILTRAGE (The Filter Problem).—P. Olinet. (*Q.S.T. Français*, June, 1928, No. 51, pp. 3–10.)

The continuation of a series of articles (see July Abstracts, "The Supply of Electricity to Radio-stations"). Former articles having dealt with rectifiers and wave-band filters, the present one concentrates on single-wave-stoppers as an adjunct to the other filters. As before, frequent diagrams and simple mathematics are used. The question of the Anode Feed both for transmission and reception having been satisfactorily settled, similar treatment of the filament supply is promised in the next article.

CONSTANT SPEED MECHANISM FOR AN ACCURACY OF 1 IN 10,000.*. (*See* Miscellaneous, "Picture Reception.")

* This cross-reference appeared by error in the July Abstracts.

STATIONS, DESIGN AND OPERATION.

TRANSATLANTISCHE TELEPHONIE (Transatlantic Telephony).—F. Anton. (*E.N.T.*, May, 1928, V. 5, pp. 221–227.)

A description of the England-America Telephone. The article includes details concerning the suppression of carrier wave and one side-band.

SOME INVESTIGATIONS OF SHORT WAVES AT NIJNI-NOVGOROD.—W. W. Grzybowski. (*Q.S.T.*, April, 1928, V. 15, pp. 9–14.)

Powers of about 25 kW. were at first used; a wavelength of about 80 m. was successful in getting strong telegraphic signals to Newfoundland and Porto Rico; but for 24-hour communication with Turkestan this was reduced to one of 20–30 m., various types of directional aerials were used, and the power cut down very greatly. Present efforts are directed to communication with Siberia, Vladivostok and Central Asia.

UN SYSTÈME FRANÇAIS D'ÉMISSION À ONDES COURTES PROJETÉES (A French system of short-wave "beam" transmission.)—M. Chireix. (*L'Onde Élect.*, May, 1928, V. 7, pp. 169–195.)

A full and authoritative account of the Ste. Assise station for communication with Buenos Ayres, Rio de Janeiro and elsewhere.

La Transmission Radiotéléphonique par Ondes Courtes Dirigées et la Station D'Essais de Communication Paris-Alger (Radiotelephonic transmission by short wave "beam," and the trial station for the Paris-Algiers service).—R. Villem. (*Rev. Gén. de l'Élec.*, 16th June, 1928, V. 23, pp. 1035–1043.)

This contains much of the same material as the article by Noël dealt with in July Abstracts.

The Mains Danger.—(*Wireless World*, 30th May, 1928, V. 22, p. 565), and

The Mains and the Earth Connection (Some Considerations when obtaining Power from D.C. Supplies).—(*Wireless World*, same issue, pp. 570–572.)

GENERAL PHYSICAL ARTICLES.

Electrical Conductivity.—W. V. Houston. (*Nature*, 2nd June, 1928, V. 121, p. 884, summarised from *Zeitsch. f. Physik*, 7th May.)

The author applies the principles of wave-mechanics to the problem of electrical conductivity, extending Sommerfeld's revived electron theory of metals. After certain assumptions, mathematical development leads to a very satisfactory account of the temperature coefficient of resistance, except in the region of super-conductivity.

The Study of the Specific Resistance of Bismuth Crystals and its Change in Strong Magnetic Fields, and Some Allied Problems.—P. Kapitza. (*Proc. Royal. Soc.*, 1st June, 1928, V. 119, Series A, pp.358–443.)

Experiments are described which were carried out with the support of the Department of Scientific and Industrial Research, on the behaviour of bismuth crystals under the very powerful transitory magnetic fields (up to 300 kilogauss) obtained by the author's new method. Among the interesting conclusions arrived at may be mentioned the suggestion that the disturbance produced by the magnetic field in the atoms of the conductor will increase the efficiency of " small collisions " (which sum up to form the " complete " collision of Sommerfield's theory), and that this will increase the resistance. Thus from a formal point of view, the effect of a magnetic field may be regarded as a decrease in the length of the free path of the electron.

Direct Evidence of Atom Building.—Millikan and Cameron. (*Science*, 13th April, 1928, abstracted in *Journ. Franklin Inst.*, June, 1928, V. 205, p. 766.)

Latest work on Cosmic Rays shows that they consist of wavelengths occurring in bands of definite frequency, not covering continuously long stretches of the spectrum. Four chief regions have been determined, which can be accounted for, according to Einstein's equation, as emitted upon the combination of positive electrons (that is, of hydrogen nuclei or protons) with negative electrons to form the atoms of light elements. The authors suggest, with reserve, that this forms the first evidence of the constructive process of atom-building.

Cosmic Rays.—(*World Power*, June, 1928, V. 9, p. 331.)

A short history of the observations, beginning in 1903, which have led to our present knowledge regarding these Rays.

Étude des Oscillations Entretenues (The Study of Sustained Oscillations).—A. Liénard. (*Rev. Gén. de l'Élec.*, 26th May, 1928, V. 23, pp. 901–912, and 2nd June, pp. 946–954.)

Continuing the work of the two Cartans, Van der Pol and others, the author gives a simple graphical solution of the equation governing several oscillating phenomena (*e.g.*, singing arc, multi electrode valves etc.), namely :

$$\frac{d^2x}{dt^2} + \omega \, . \, f(x) \frac{dx}{dt} + \omega^2 x = 0$$

He shows that for the general case there is one solution for the stable oscillatory condition and one only, and indicates processes for the evaluation of the amplitude of the oscillations, and a lower limit to the duration of the oscillating condition.

The Velocity of Sound in Liquids at High Frequencies by the Sonic Interferometer.—Hubbard and Loomis. (*Phil. Mag.*, June, 1928, V. 5, pp. 1177–1190.)

Report of Work of Bartol (Research) Foundation.—W. F. G. Swann. (*Journ. Franklin Inst.*, June, 1928, V. 205, pp. 767–829.)

The problems dealt with are : (1) The emission of electrons from wires under the influence of intense electric fields. The use of different sized wires has enabled del Rosario to produce different surface fields for the same differences of potential, or different differences of potential for the same surface field, and to obtain apparently conclusive evidence that the total potential difference, and not the field at the surface, is the factor which determines primarily the magnitude of the current. This leads to the suggestion that the electrons are given off by thermionic emission, caused by the bombardment of positive ions (emitted from the surrounding cylindrical anode and travelling to the wire, gaining as they go energy proportional to the difference of potential) which raise the temperature of the wire in the extreme local regions where they hit. Experiments are being continued to determine whether the emission of X-rays from the cylinder as a result of the electron bombardment may play a part in maintaining the current. (2) The excitation of spectra in mercury vapour by electron impact (Maxwell). (3) A possible effect of the Cosmic Radiation in stimulating Radioactivity. Maxwell proposes to measure the activity of a radioactive preparation in a deep mine, to see if its radioactivity is appreciably diminished, as it would be if Perrin's suggestion is true that cosmic radiation produces radiation from radioactive materials in the same kind of way that the emission of electrons from atoms can be brought about by X-rays. (4) The production by X-rays by positive ions (Barton). The protons, when obtained, must be led out of the compartment containing hydrogen sufficiently dense to allow an appreciable production of protons, into one where the pressure is low enough to allow the production of X-rays. So far, a beam of 10^{-4} ampère has been obtained and it is hoped to improve this to 10^{-3}. No results are yet announced as regards the production of X-rays. A cheap and simple device for measuring the high potentials used comprises a metal hydrometer floating in transformer oil and surrounded by a metal cylinder. The hydrometer has two light guides which keep it central and through which it is connected to earth. (5) The loss of energy by electrons in the production of characteristic X-radiation. Method described but no results announced. (6) An attempt to detect a magnetic field as a result of the rapid rotation of a copper sphere (Swann). The question arises in connection with endeavours to account for the earth's magnetic field. Method and precautions against spurious effects are described, and curves are given showing the production of a field rising in one case (with increased speed of rotation) from 0 to 2×10^{-4} Gauss. (7) The effect of an electric field on the production of double refraction in sodium vapour (Bramley). Results were in agreement with the old ideas embodied in Voigt's theory, so long as the temperature was above 230 degree C., but below this temperature they departed from the theory; thus confirming the modern atomic idea of the two intermittently-appearing virtual oscillators and providing information as to the differences in the action of the electric field on the two kinds of virtual oscillators.

Further problems will be dealt with in next month's Abstracts.

PIEZO-ELECTRIC QUARTZ RESONATORS: AN OPTICAL INTERFERENCE METHOD OF OBSERVING THEIR MODES OF VIBRATION.—(*Electrician*, May, 25, 1928, V. 100, p. 576.)

A short description of the demonstration at the Royal Society Conversazione of Dr. Dye's method, by which the nodes and antinodes on the polished surface of a quartz plate excited by an alternating electric field (of adjustable frequency) are made visible and can be photographed.

PIEZO-ELECTRIC EXCITATION OF LONGITUDINAL, TRANSVERSE AND TORSIONAL VIBRATIONS IN QUARTZ RODS.—Giebe and Scheibe. (*Zeitschr. f. Physik*, V. 46, 9–10, 1928, pp. 607–652.)

The electrical glow produced in a rarified gas is used to make visible the distribution of the piezo-electric charges. Photographs can also be taken.

MECHANICAL OSCILLATIONS OF QUARTZ CRYSTALS.—Wachsmath and Auer. (*Zeitschr. f. Physik* V. 47, 5–6, 1928, pp. 323–329.)

Optical methods were supplemented by a method using lycopodium powder.

Propagation velocity was found to vary from 2,250 at a frequency of 200 kc. to 2,700 at 400 kc.

THE INFLUENCE OF VARIOUS GASES UPON WIRE VIBRATION IN A CORONA DISCHARGE TUBE.—Snyder and Evans. (*Journ. Sci. Instruments*, May, 1928, V. 5, pp. 166–167.)

In corona-discharge tubes of the wire and co-axial cylinder type, the vibration of the wire under the influence of an A.C. discharge is well known. It is normally prevented by having the wire carefully centred and under tension. The writers found that such means were perfectly satisfactory for tubes containing air, ammonia, oxygen, hydrogen or hydrogen-nitrogen mixture, but failed with pure nitrogen, methane or carbon monoxide under the particular conditions of their experiment, where a 60-cycle frequency and 13,700 volts pressure were used.

DEMONSTRATIE VAN EEN NIEUW PHOTOELECTRISCH EFFECT (Demonstration of a new photo-electric effect).—F. M. Penning. (*Physica*, V. 8, No. 4, 1928, pp. 137–140.)

The sparking-potential of a discharge tube, containing Neon and a small percentage of Argon, is increased by 50 v. when the gas between the electrodes is exposed to intense radiation from another Neon tube. The effect may be demonstrated by using an intermittent glow discharge and a loud-speaker: the note is lowered when the light from the second Neon tube falls on the first. The effect is due to the Neon light partly destroying the metastable atoms, thus diminishing the number of ionised argon atoms present.

KATHODENZERSTÄUBUNG (Wearing-away of Cathodes by emission of particles).—(*E.T.Z.*, 17th May, 1928, p. 765.)

A paragraph summarising the work of Güntherschulze, published in *Zeit. Phys.*, V. 36 and 38, in which he investigates cathodes of 24 different elements in hydrogen. Some six of these behave in an anomalous way, both in the distribution of the deposit, and because they give a deposit even when disconnected from the cathode and simply placed in the path of the discharge, the presence of hydrogen ions being sufficient to produce what is, in their case, an electro-chemical process. The normal, electrical process is exemplified by silver in hydrogen, which behaves according to the law $Q = \frac{CV}{cp}$ where Q is the quantity of the silver deposited per a.h., V is the cathode drop of potential, c is the distance between electrodes and p is the gas-pressure. The constant C is for silver in hydrogen 0.868.

WHAT IS AN ATOM?—P. R. Heyle. (*Scientific American*, July, 1928, pp. 9–12.)

The newest idea of the atom is the "Schrödinger" atom, which has replaced the Bohr conception of a miniature solar system of electrons rotating about a central proton. The author, physicist in the Bureau of Standards, deals in a popular way with these and older ideas, and the reasons for abandoning each in turn.

LA THEORIE DE MAXWELL ET L'ÉLECTRICITÉ MODERNE (Maxwell's Theory and Modern Electricity).—L. La Porte. (*Q.S.T. Français*, June, 1928, No. 51, pp. 52–56.)

The objects of the writer is to show, without considering high frequency currents, and without using a single mathematical symbol, how matter and electricity are related, both proceeding from ether whose normal condition has been modified.

MISCELLANEOUS.

A GALVANOMETRIC RELAY WITHOUT CONTACTS.—(*Bull. de la Soc. Franç. des Elec.*, April, 1928, V. 7, pp. 351–352.)

The galvanometer needle carries at its end a small differential thermo-couple. When this is swung under a small electric heater, the thermo-electric current produced works a polarised relay. The position of the heater is adjustable with regard to the galvanometer scale. The instrument is brought out by the Cambridge Scientific Instrument Company.

RADIO APPLIED TO PETROLEUM PROSPECTING.—G. R. Chinski. (*Q.S.T.*, March, 1928, V. 15, pp. 43–46.)

Wireless plays merely a subsidiary (though important) part in the "Seismic" method described, providing a means of synchronisation as well as of inter-communication.

METHODS FOR INVESTIGATION OF LOUD SPEAKERS.—(*Bull. de la Soc. Franç. des Elec.*, April, 1928, V. 7, pp. 393–399.)

A discussion of various methods, including the use of a Rayleigh disc and of Gerlach's device using an alternating magnetic field to oppose the vibrations of a diaphragm.

VERSUCHE MIT PHOTOZELLEN FÜR BILDFUNKZWECKE (Experiments with Photo-cells for Picture-Wireless purposes).—W. Nestel. (*Rad. f. Alle*, June, 1928, V. 7, pp. 283–288.)

Investigations start with a determination of the Sensitivity (measured by the photo-electric current per metre-candle power of illumination) and the Inertialess property (measured by the number of impulses per second it can deal with), continue with light-telephony, in which the light from an arc-lamp is modulated by speech and concentrated into a ray which carries to the receiving photo-cell; and finally deal briefly with Picture- or Facsimile-Wireless.

LES STATIONS DE SIGNAUX HORAIRES (Time-Signal Stations).—L. de la Forge. (*Q.S.T. Français*, June, 1928, No. 51, pp. 45–51.)

A continuation of the article mentioned in the July Abstracts. The present instalment deals with Asia and Africa. Full tables are given.

LA RADIODIFFUSION BRITTANNIQUE DÉCRITE PAR ELLE-MÊME (British Broadcasting described by itself).—L. de la Forge. (*Q.S.T. Français*, June, 1928, No. 51, pp. 20–26.)

Broadcasting in France will have to be organised properly and promptly. In order to profit by the experiences of other countries, the author now brings to the public attention the recently published "B.B.C. Handbook" from which he quotes at length.

FERNABLESUNG VON ZEIGERSTELLUNGEN MITTELS HOCHFREQUENZ (Distant-reading of Meters, etc., by H. F. Method).—Hollmann and Schultes. (*E.N.T.*, May, 1928, V. 5, pp. 217–221.)

A method is described which reduces to a minimum the work (against friction, etc.) which has to be done by the moving-part of the meters, and thus permits its application to delicate instruments. The moving-part carries with it the rotor of a variable condenser, and thus changes the wave-length of oscillations which are carried (either by wireless or wired wireless) to the distant receiver.

GEOPHYSICAL METHODS OF LOCATING MINERALS.—(*Engineering*, 8, June, 1928, V. 125, pp. 696–697.)

A summary of papers read before the American I.M. and Met. Eng. Many of the writers deal with the use of the Eötvös Torsion Balance method (a "Gravity" method) but various electrical and magnetic methods are mentioned, as well as a Seismic method depending on the recording, by a series of seismographs along a profile line, of the vibrations set up by an explosion; the velocity of transmission varying with the character of the sub-strata.

MÉFIEZ-VOUS DES CHIFFRES INSCRITS SUR LES APPAREILS (Distrust the figures inscribed on Component Parts).—J. Granier. (*Q.S.T. Français*, June, 1928, No. 51, pp. 11–13.)

The value of an Inductance, the capacity of a condenser or of an accumulator, the power of a motor, are not constant quantities; they vary according to the conditions of us. Therefore the marked values of such pieces of apparatus can only certainly apply when they are used under conditions similar to those under which they were tested. The present article deals with condensers measured ballistically.

AMERICA'S SHORT WAVE DEVELOPMENT.—(*Electrician*, 8, June, 1928, V. 100, p. 648.)

A paragraph noting the additional short-wave facilities asked for from the Washington Government, for new telephone and telegraph channels. Three more channels to Europe are desired, as well as others to the Argentine, the Phillipines, China, Japan, Australia, Dutch East Indies, Liberia, Cuba, Chili, Brazil, Egypt, the Republic of Georgia, and elsewhere.

SUR L'UTILISATION DE L'ÉNERGIE THERMIQUE DES MERS (The Utilisation of the thermal energy of seas).—Claude and Boucherot. (*Comptes Rendus*, 4, June, 1928, V. 186, pp. 1491–1496.)

An account of the preliminary trials, on 1st June, 1928, of the authors' plant for deriving power from the different temperatures (at surface and at great depth) of the water of tropical seas. In this trial (in Belgium) the difference in temperature (about 10 degrees) was produced artificially, and the plant worked with perfect success. The turbine-driven dynamo gave an output of nearly 60 kW., of which about 70 per cent. was available for power. The next step will be on the coast of Cuba, where a complete plant is to be installed under actual working conditions.

Machines à Courant Continu avec ou sans Collecteur (D.C. generators with or without commutators).—(*Bull. de la Soc. Franç. des Elec.*, April, 1928, V. 7, pp. 405–428.)

A long discussion on the much sought-after commutatorless generator (*c.f.* Abstracts for July, "Dynamo Unipolaire Poirson").

La Remise à l'Heure Automatique des Pendules par T.S.F. (Clock-setting by Wireless).—(*Bull. de la Soc. Franç, des Élec.*, April, 1928, V. 7, pp. 399–404.)

Discussion of the paper mentioned in the July Abstracts.

Picture Reception (Recent Important Developments in Home-reception Process).—(*Wireless World*, 23rd May, 1928, V. 22, pp. 542–546.)

Describes a new picture receiver suitable for use with a broadcast receiving set; the difficulties of synchronising have, it is stated, been successfully overcome by the new mechanism which will run the cylinder continuously with an accuracy of not less than one part in ten thousand. Control by valve oscillator or pendulum is dispensed with.

The Measurement of Sound-absorption in a Room.—V. O. Knudsen. (*Phil. Mag.*, June 1928, V. 5, pp. 1240–1257.)

A Rectifier for High Tension Electricity.—(*Génie Civil*, 2nd June, 1928, V. 92, p. 531.)

In the course of a 5-page article on the precipitation of dust by electricity, a mechanical rectifier is described and illustrated which rectifies A.C. at 50,000 v. and 50 frequency.

Loud Speaker Location.—A. H. Davis. (*Wireless World*, 20th and 27th June, 1928, V. 22, pp. 651–655 and 678–682.)

The first article deals with "Tracing Sound Pulses by Photography in the Auditorium" (reverberation: work of the National Physical Laboratory; distortion due to draping of room; shadows cast by invisible gases; photographing sound pulses), the second with "How Resonances in Small Rooms may affect Loud Speaker Reproduction" (resonances in small rooms; loud speakers in large halls; directive action of loud speakers; difficulties when microphone and loud speaker are in the same hall).

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPRECOJ DE CIRKVITOJ.

La Ekvivalenta Indukteco kaj Kapacito de Anteno kun Enmetita Agorda Bobeno aŭ Kondensatoro.

Redakcia noto (super la ĉefliteroj de Prof. Howe), kiel daŭrigo de tiu en la antaŭa numero kaj naskita de la letero de D-ro. Palmer (ĉi-supre). La pligrandigo de ondolongo per enmeto de induktanco, kaj la malpligrandigo de ondolongo per enmeto de kondensatoro, estas diskutitaj detale, kun kurvo montranta la efekton de ĉi tiuj ŝarĝoj ĉe la ekvivalenta indukteco de la anteno. Oni atentigas, ke la traktado de D-ro. Palmer nerimarkas la ŝanĝon de la ekvivalenta indukteco de l'anteno dum indukteco aŭ kapacito estas enmetita laŭserie kun ĝi.

Pri la Ekvivalenta Indukteco kaj Kapacito de Anteno.

Letero (en fako de korespondado al la Redaktoro) de D-ro. L. S. Palmer, naskita de la Redakcia artikolo en la antaŭa numero. La Redakcia kritiko estas diskutita kaj kurvoj donitaj montrantaj rezultojn obtenitajn de (1) Teoria Formulo, (2) Formulo de Howe, (3) Formulo de Palmer.

Reaktancaj kaj Admitancaj Kurvoj Aplikitaj al Agorditaj Cirkvitoj kun kaj Sen Rezisteco.

Daŭrigita el antaŭa numero. La nuna parto studas la ĝeneralan ekzemplon de resonanca cirkvito, en kiu la rezisteco de la bobeno kaj la elfluebleco de la kondensatoro estas ambaŭ kunkonsideritaj. La seria resonanca cirkvito estas unue pritraktita, kaj partaj vektoraj diagramoj jam donitaj, estas kombinitaj por la tuta cirkvito kaj resonanca kurvo desegnita. La rezonado estas poste aplikita al la ekzemplo de paralela resonanco, kaj vektoraj diagramoj kaj resonancaj kurvoj estas desegnitaj por kelkaj malsamaj kondiĉoj de rezisteco kaj elfluebleco.

RICEVADO.

Sistemo por Kontraŭbatali la Efekton de Statiko.—E. A. Tubbs.

La sistemo priskribita estas uzata en la ricevaj stacioj de la *Federal Telegraph Company* de San Francisko. La cirkvito estas tiu de la ekvilibrigita modulatoro (ŝuldata al Carson), kiu estas jam uzata en portaj sistemoj kaj transatlantika telefonio, la ricevita signalo estante aplikita al la kradoj en fazo kaj al la loka heterodino en kontraŭfazo. Oni montras ke, per alĝustigo de la loka oscilado, alĝustigo estas trovebla, kie ia ajn interfero enkondukita en la elmeton neniam estos plilaŭta ol la dezirita signalo.

Aldonaĵo pritraktas la teorion de la sistemo.

LA UZADO DE ALTERNKURENTO POR VARMIGI VALVAJN FILAMENTOJN.—C. W. Oatley.

Oni unue aludas al la fakto, ke kiam riceva valva filamento estas senpere varmigita per a.k.—aparte de l'ekzemplo de la sensepende varmigita katodo—la a.k. tono estas aŭdita en la kaptelefoniloj aŭ laŭtparolilo. Ĉi tio eble povas esti kaŭzita de variado de filamenta temperaturo kaj de ŝanĝiĝado de l'efektiva krada potencialo, laŭ ĉu ĝi estas momente konektita al la negativa aŭ pozitiva fino de l'filamento.

Ĉi tiuj ekzemploj estas ambaŭ konsideritaj detale, kaj oni konkludas, ke filamentoj senpere varmigitaj per a.k. ne taŭgas por la detektora ŝtupo, sed ke estas eble elimini la zumadon, kiam la valvo estas uzita kiel amplifikatoro.

HELPA APARATO.

MIKROFONAJ AMPLIFIKATOROJ KAJ TRANSFORMATOROJ.—H. L. Kirke.

Post enkonduka sekcio, la aŭtoro diskutas evoluiĝon de progresado, frekvencan amplekson de muzikaj instrumentoj, korektecon de reproduktado, distordadon de frekvenca karakterizo, k.t.p. Li poste turnas sin al longa diskutado pri la transformatoro, enmeta kaj elmeta, la intervalva transformatoro estante konsiderita kiel elmeta transformatoro, kvankam li indikas, ke la ŝoka kuplo estas preferinda.

La kondiĉoj por "detranĉado" je diversaj frekvencoj estas konsideritaj, kaj oni montras, ke estas necese, ke la transformatoro havu altan primarian induktecon por bona frekvenca karakterizo. Magneta elflueto estas ankaŭ diskutita, kun ĝia efekto ĉe frekvenca karakterizo, kaj la funkcio de l'transformatoro funkcianta sub kondiĉoj de parigita impedanco. La enmeta transformatoro estas poste pritraktita. La diskutado estas laŭ vidpunkto de transformatoro tiel desegnita, ke ĝia primario havas impedancon, kiu egalas la mezan impedancon de la enmeta cirkvito. Tipaj detaloj estas donitaj pri transformatoro por 500-oma enmeta impedanco, havanta "detranĉon" de 0.95 je 50 kaj 9,000 periodoj ĉiusekunde. La kerna materialo estas ankaŭ diskutita kaj ĝia efekto je la funkciado de la transformatoro.

La artikolo estas finota en la venonta numero.

STACIOJ : DESEGNADO KAJ FUNKCIADO.

INTERESA NOVA 100-VATA APARATO.

Mallonga priskribo estas donita, kun fotografaĵoj, de nova 100-vata fiks-ondolonga telefonila aparato lastatempe produktita de la Marconi'a Kompanio.

La ondolongo povas esti fiksita inter la limoj de 150 kaj 400 metroj (fiksita je la tempo de instalo). La aparato estas aparte taŭga por uzado sur malgrandaj ŝipoj, lumturoj, k.t.p., kie sperta funkciisto ne dejoras.

DIVERSAĴOJ.

RESUMOJ KAJ ALUDOJ.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

DISTRIBUADO DE EŬROPAJ BRODKASTAJ ONDOLONGOJ—KELKAJ NOVAJ VIDPUNKTOJ.—S. Lemoine.

La aŭtoro estas ĉef-inĝeniero de la Sveda Telegrafa Administrado kaj membro de la Teknika Komitato de *l'Union Internationale de Radiophonie* (Internacia Unio de Radiofonio).

Post enkonduka diskutado pri la Ĝeneva plano, la aŭtoro mallonge traktas pri la rezolucioj aprobitaj de la Washington'a Konferenco kaj ilia signifo. Li poste diskutas areon kaj loĝantaron kiel principojn regantajn la distribuadon de ondolongoj, urĝante, ke ĉiu lando devus havi nombron da frekvencoj, kiu estas funkcio de ĝia areo kaj loĝantaro, esprimita kiel procentaĵo, la unua rigardita kiel tuto kaj la ĉi-lasta kiel duono. Tabeloj estas donitaj pri komparaj nombroj por ondolonga distribuado laŭ proporcioj de ĉi-tiuj faktoroj.

Li poste konsideras la principon de la komuna lokigo de la ondolongoj kaj faras proponon por la enkonduko de "ondolonga ekvivalento," kiu ekkonas la servan valoron de la diversaj ondolongoj laŭ konataj leĝoj pri la variado de maldenseco laŭ frekvenco. Ĉi tiu ondolonga ekvivalento estas sugestita kiel la kubradiko de la proporcio inter la inversaj valoroj de frekvencoj. Tabelo de ondolongoj ekvivalentaj pro diversaj frekvencoj estas donita, kaj la aplikado de la principo estas montrita. Ekskluzivaj kaj partoprenaj ondolongoj estas poste diskutitaj, la aŭtoro sugestante la malpliigon de la ĉi-lasta de 16 ĝis 12. Laste, grupa distribuo de ondolongoj estas sugestita, t.e., ke la ekskluzivaj frekvencoj asignitaj al iu ajn lando devus esti en apudaj frekvencaroj.

Resumo kaj finaj observadoj finas la artikolon.

AN AMALGAMATION.

Those of our readers who are photographers will be interested to learn that our sister journal, *The Amateur Photographer* and its contemporary *The New Photographer*, have been merged into one publication. The combined journal, which is known as *The Amateur Photographer, Incorporating The New Photographer*, will continue to be published from these offices every Wednesday, price 3d., and obtainable from newsagents, bookstalls and leading photographic dealers. All the features of the two journals which have proved most attractive to readers in the past are embodied in the combined paper, and every effort will be made to make the one weekly journal more and more interesting and valuable to amateur photographers in the practice of their hobby.

Some Recent Patents.

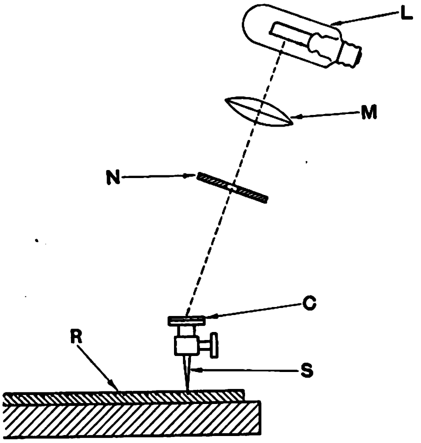
The following abstracts are prepared with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each.

PHOTO-ELECTRIC "PICK-UPS."

(*Application date, 11th January,* 1927. *No.* 288,711.)

A light-sensitive cell is used to convert the mechanical movements of a gramophone stylus into electric current-variations for subsequent reproduction in a loud-speaker. As shown, a selenium cell *C*, having a plane surface, is mounted on the top of the stylus *S*, which is vibrated by the sound record *R*. A lamp *L* and lens *M* direct a concentrated ray of light through a perforated screen *N* so that it impinges at an acute angle on the sensitive cell *C*.

The vibrations of the stylus alter the angle of the cell with respect to the incident ray, so that the intensity of illumination varies with each movement, the interposition of the perforated screen *N* serving to increase this effect. The cell *C* is connected in series with a battery in the input circuit of a thermionic valve, by which the resultant current fluctuations are suitably amplified.



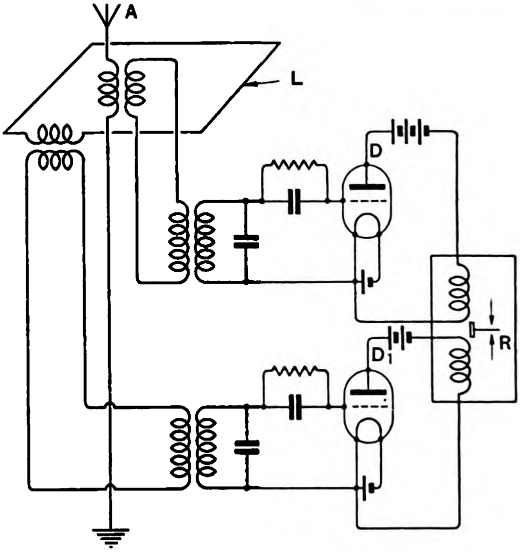
Patent issued to The British Thomson-Houston Co., Ltd.

PREVENTING FADING EFFECTS.

(*Convention date* (*Germany*), *6th September,* 1926. *No.* 277,039.)

It has been shown in connection with investigations into the behaviour of different combinations of vertical and horizontal receiving aerials, relatively to the angle of incidence of the incoming waves and their plane of polarisation, that a horizontal frame of correct dimensions will pick up an amount of energy equivalent to a vertical aerial, provided that in both cases the plane of polarisation is such that maximum energisation takes place. The resultant strength of reception is, however, also dependent upon the relative phase relations of the respective aerial currents.

According to the present invention, in order to rule-out fading variations arising from fluctuations in the plane of polarisation, the currents from each aerial are fed to separate detectors. As the output from each valve varies as the square of the instantaneous aerial current, the final result is made independent of the instantaneous phase or vector relation existing in each aerial. As shown, a vertical aerial *A* and horizontal loop *L* are separately coupled to two detectors, the output currents from which are combined to operate a common recording device *R*.



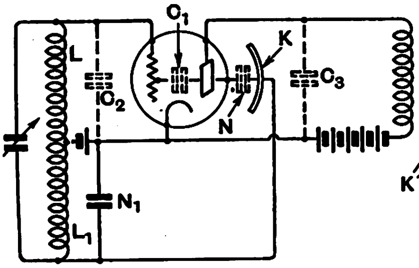
Patent issued to the Telefunken Co.

A NEW BALANCED AMPLIFIER.

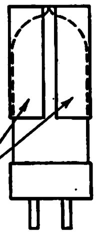
(*Convention date* (*U.S.A.*), *11th January,* 1927. *No.* 283497.)

When using the ordinary methods for neutralising the effect of interelectrode capacity, difficulty is experienced in securing an absolutely true balance, particularly at high frequencies. In Fig. *a* the dotted-line condensers C_1, C_2, C_3 represent the effective valve capacities, including the external leads, when the valve is in actual operation, whilst *N* represents the usual balancing condenser inserted in series with the plate and the split input *L*, L_1. So far the arrangement is ineffective at high frequencies because the capacity C_2, in parallel with the input coil *L*, spoils the symmetry of the divided circuit.

According to the invention, the balance is restored by inserting a condenser N_1 in shunt across the coil L_1 and equal in value to the condenser C_2 as shown. Further the plate of the valve is so arranged that it becomes a common condenser plate between the capacities C_1 and N. This is effected by providing an external element K in the form of a split cylinder as shown in Fig. *b*. This encircles the glass bulb with a sliding fit so that the effective capacity value, represented by the condenser N, can be adjusted as desired.



(a)



(b)

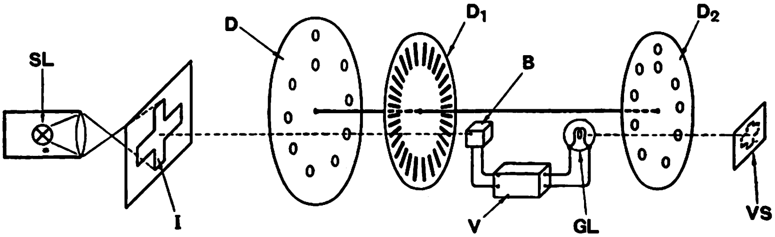
Patent issued to The Marconi Co., Ltd.

TELEVISION APPARATUS.

(*Application date*, 15*th October*, 1926 ; 26*th January and* 10*th March*, 1927. *No.* 288,882.)

The apparatus is described as a means for providing a visible image of an object which is in darkness, an effect to which the term "Noctovision" has since been applied by the inventor. The arrangement is shown and is used when the object to be viewed is some distance away from the observer. A searchlight projector *SL* is closed by a relatively-thin diaphragm of ebonite, which cuts off all visible light but passes infra-red rays on to the object so as to form an invisible image *I*.

This is explored by the familiar Baird system of rotating obturator discs D, D_1. The interrupted infra-red rays are then projected on to a bolometer *B* or similar device sensitive to such energy. The current from the bolometer is passed through an amplifier *V* to a glow-discharge lamp *GL*, which operates in conjunction with an exploring disc D_2 to produce a visible image of the original "dark" object on the viewing screen *VS*. The local and distant exploring devices D, D_1 and D_2 are mounted on the same rotating shaft so as to ensure synchronisation under all conditions.

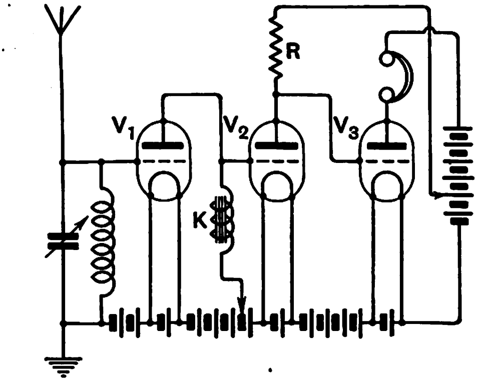


Patent issued to Television Ltd., and J. L. Baird

INTERVALVE COUPLINGS.

(*Application date*, 10*th March*, 1927. *No.* 289,217.)

To avoid distortion due to the use of grid-leak rectification, and at the same time to provide a simplified system of intervalve coupling, where an extended source of high-tension voltage is available, the circuit arrangement shown is adopted. The plate of the first valve V_1 is connected directly to the grid of the next valve V_2 and to a point on the H.T. supply through an impedance *K*. The filament supply to the second valve is tapped off from the common supply at a point of higher potential than the plate voltage on the first valve, so that successive electrodes are maintained at effective operating potentials. A similar arrangement is adopted in connection with the filament supply to the valve V_3.



The grid-bias on the first valve is such as to secure anode-bend rectification, the subsequent low-frequency current variations being communicated from one valve to the next through the choke *K* and the resistance coupling *R*. The system is particularly adapted for use with mains supply units.

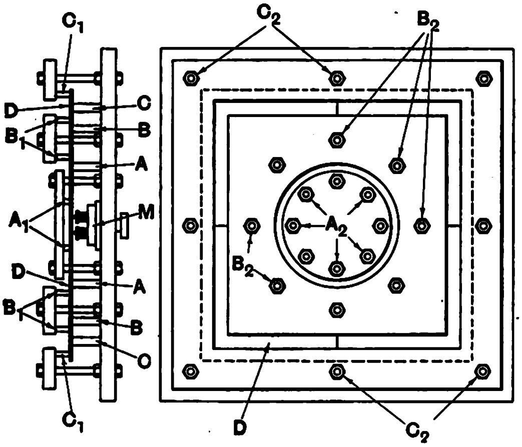
Patent issued to J. F. Johnston.

LOUD-SPEAKER DIAPHRAGMS.

(*Application date*, 4*th January*, 1927. *No.* 289910.)

In order to prevent distortion and to ensure a uniform sound response over a wide range of frequencies, the vibration of the diaphragm is damped by a number of supporting points, distributed over both sides of its surface but separated therefrom by small air-gaps of adjustable width.

Fig. *a* shows a cross-sectional elevation of a square diaphragm D energised by a magnetic system M and having a number of inner supports A, B, C and outer supports A_1, B_1, C_1 arranged symmetrically at nodal points over the vibrating surface. Fig. *b* is a front elevation showing the distribution of the posts A_2, B_2, C_2, carrying the outer supports A_1, B_1, C_1.



(a) (b)

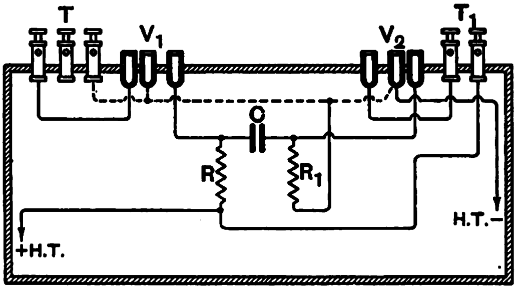
In this way it is stated that the diaphragm vibrations, usually conceived in terms of appreciable mechanical movements, are restrained and limited to molecular vibrations, so that the whole of the audible energy is converted into molecular vibratory energy, which it is stated results in an accurate reproduction throughout a wide frequency-range without distortion or blasting.

Patent issued to F. and M. M. D. Clutsam.

MASS PRODUCTION SETS.

(*Application date, 10th February, 1927. No. 290350.*)

In the case of resistance-capacity coupled sets, the cost of the intervalve coupling units is relatively small in comparison with that of the high or low tension batteries or the actual valves. The inventors accordingly propose to incorporate suitable coupling-units with say the high-tension battery, so that the latter practically comprises a wired receiver, to which only the valves need be added to enable it to function.



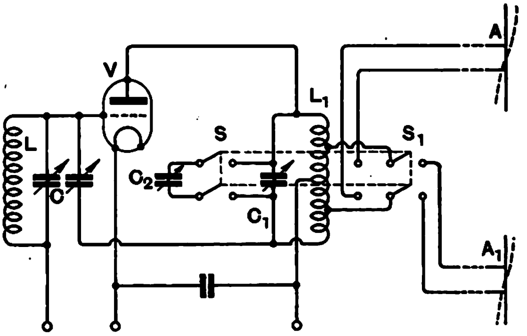
The Figure shows a high-tension dry battery fitted with suitable terminals, T, T_1, valve-sockets V_1, V_2, and the necessary high-resistances R, R_1 and fixed condenser C to form the coupling circuit. The latter are preferably embedded in the insulating material which is used to fill up the interstices in the assembled battery and to insulate the various connections. Alternatively the construction may be applied to low-tension dry-cell batteries. Or both batteries may be moulded together and designed so as to last for approximately an equal period, so that the whole receiver is contained in one compact unit.

Patent issued to The British Thomson-Houston Co., Ltd.

SHORT-WAVE SIGNALLING.

(*Convention date (U.S.A.), 5th May, 1927. No. 289875.*)

In short-wave signalling, such as the well-known Beam system, it is found that the most efficient working wave-length varies from 15 to 30 metres during the daytime, to from 30 to 60 metres at night. It follows that in order to maintain a 24 hours' service it is necessary to provide means for expeditiously changing the signal frequency from time to time. In certain cases, the terminal stations are equipped with two or more independent transmitters for this purpose. The present invention provides a method for making the necessary change-over when using only a single transmitter.



As shown in the Figure the amplifying stage V of the transmitter is adapted to be used either for straight amplification from an input circuit LC tuned say to a wavelength of 40 metres, or for frequency-multiplication to an harmonic say of 20 metres. With this object in view the output inductance L_1 is shunted by two condensers C_1, C_2 of such value that when the switch S is closed, the working frequency corresponds to a wavelength of 40 metres, whilst when it is opened the aerial supply is tuned to 20 metres. A second switch S_1 is provided to connect the H.F. supply to a 20-metre bank of aerials A_1 or to a 40-metre aerial system A.

Patent issued to The Marconi Co., Ltd.

EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. V. SEPTEMBER, 1928. No. 60.

Editorial.

A Chapter in the History of Radio Measurements.

AT an international conference in connection with the accurate determination of time held in Paris in October, 1912, Prof. Schmidt of Halle, and Dr. Robert Goldschmidt, of Brussels, proposed the formation of an organisation to co-ordinate the efforts which were being made in various countries to investigate the propagation of radio waves and to develop radio measurements. Dr. Goldschmidt not only placed his powerful transmitting station and laboratories at Laeken, near Brussels, at the disposal of the organisation, but gave 50,000 francs to cover the preliminary expenses. In October, 1913, a meeting was held in Brussels at which Mr. Duddell was elected President, Prof. Max Wien vice-president, and Dr. Goldschmidt secretary; the other members of what became known as the International Scientific Radiotelegraphic Commission were as follows:—Abraham (Paris), Ferrié (Paris), Benndorf (Graz), Schmidt (Halle), Vanni (Rome), and Wulf (Holland).

A provisional programme was drawn up and consisted of four items, viz.: (1) To determine the best means of ensuring constancy in the signals sent out from Laeken; (2) to make relative measurements of the variation in signal strength from day to day at different receiving stations and with different wavelengths; (3) to compare signal strengths in different directions and at different distances; (4) to make simultaneous measurements of atmospheric disturbances.

In each country represented on the Commission a national committee was set up, the British National Committee being constituted as follows: Mr. Duddell, Dr. Eccles, Prof. Howe, Sir Oliver Lodge, Prof. Marchant, Sir Henry Norman, Prof. Thompson. This committee met several times during 1913-1914, and discussed, among other things, the efforts of several of the members to measure the strength of the signals emitted by Laeken and by the Eiffel Tower. The Commission met for the second time at Brussels on the 6th, 7th and 8th of April, 1914; the writer was unable to be present, but England was represented by Messrs. Duddell, Eccles and Marchant. In June, 1914, was published the first Bulletin of the Commission containing an account of the proceedings at the two meetings. This first Bulletin was destined to be the last, and its ambitious plans for international co-operation in radiotelegraphic measurement were completely shattered by the outbreak of war within two months of its publication. On the approach of the German army the transmitting station at Laeken was completely destroyed. When conditions once again permitted the resumption of such schemes of international co-operation in radiotelegraphic measurement, the subject had developed in a way which could not have been foreseen in 1914.

As very few of our readers will have seen a copy of the Bulletin, or even have heard of the Commission and its short-lived activities, we thought that it would be of interest to recall this pre-war organisation and to devote a few pages to describing what was done by the members of the British National Committee during the spring of 1914.

The transmitter at Laeken employed a spark gap consisting of a copper tube with its axis normal to a copper plate; the spark jumped from the end of the tube to the surface of the plate. The tube formed a nozzle for a powerful air blast which played directly on to the plate and escaped radially. The oscillatory spark-gap circuit was loosely coupled to the aerial which was tuned to the same frequency. The wavelength employed was 3,500 metres. The results obtained from this station were not so good as those obtained from the Eiffel Tower spark transmitter, which worked on a wavelength of 2,200 metres and which sometimes, thanks to the co-operation of General Ferrié, sent out a succession of 10-second dashes. Measurements were made by Mr. Duddell at his laboratory in Victoria Street, London, by Prof. Marchant at Liverpool University, and by the writer at South Kensington. Whereas the two former members, in common with all the other observers, used some form of detector in combination with a delicate galvanometer—Prof. Marchant obtained photographic records by means of an Einthoven galvanometer—the writer measured the high-frequency current set up in the receiving aerial by means of a thermo-galvanometer, and thus made a direct measurement of the energy collected by the receiving aerial from the passing wave.

The aerial employed consisted of a single No. 14 copper-coated steel wire suspended from the tower of the Imperial Institute, 260 feet above the ground and carried in a single span of 530 feet to a chimney stack on the City and Guilds Engineering College. It had a fundamental wavelength of 900 metres, and was connected to earth through several tuning coils wound with 27/36 multiple-stranded silk-covered wire. These coils formed the primary winding of a variable mutual inductance, the secondary of which was wound with similar wire; the object of this will be seen in a moment. When the aerial is tuned to exact resonance with the received wave it acts as a non-inductive resistance R_a; R_a is the equivalent resistance of the aerial. If now the heater of a thermo-galvanometer is inserted between the aerial and earth the aerial current is reduced from E/R_a to $E/(R_a+R_i)$, where R_i is the heater resistance. Although the total energy $E^2/(R_a+R_i)$ abstracted from the wave is reduced, that supplied to the heater increases as R_i is increased until it reaches a maximum when $R_i = R_a$. As R_i is still further increased, I^2R_i decreases.

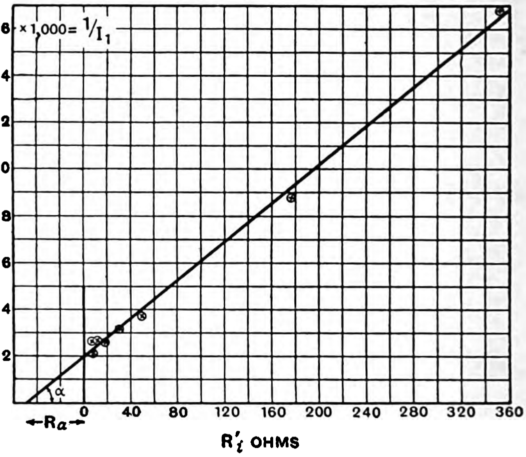


Fig. 1.

Although the writer was fortunate in possessing a very sensitive Duddell thermo-galvanometer, the resistance R_i of its heater was 1,175 ohms, which made it quite unsuitable for inserting directly in the aerial. The heater was therefore coupled to the aerial by means of what was really a current transformer; it was connected between the terminals of a coil of inductance L_2, which was coupled to the aerial tuning coil. If the mutual inductance is M it is easy to show that this is equivalent to inserting a resistance R_i' directly in the aerial, where

$$R_i' = R_i \frac{\omega^2 M^2}{R_i^2 + \omega^2 L_2^2}$$

We neglect the resistance of the coil in comparison with that of the heater, and we neglect the error due to the wave being damped and not continuous. Any effect of the coupling on the tuning of the aerial can be corrected by retuning. It will be seen that by varying M, that is, by varying the coupling between the coils, the equivalent resistance inserted in the aerial can be varied. By adopting this arrangement we were enabled to determine not only the power, and thus the E.M.F. induced in the aerial, but also the equivalent resistance of the aerial. To determine the latter, it was only necessary to vary R_i' until the maximum power was absorbed by the heater; that is, until the deflection was a maximum; this occurs when $R_i' = R_a$.

We shall illustrate the method by giving the results of a test made on long dashes sent out from the Eiffel Tower at a wavelength of 2,200 metres, with about 45 amperes in the transmitting aerial between 7 and 10 p.m. on Thursday, 26th March, 1914. The calibration of the thermo-galvanometer gave the result $I = 5.78\sqrt{\theta}$, where θ is the deflection in mm. and I is in microamperes; a deflection of 50 mm. was thus obtained with a current of 41 microamperes. The results of the measurements are given in the table; L_1 is the self inductance of the primary coil; that is, of the part of the aerial tuning inductance which was used for coupling; L_2 the self inductance of the secondary coil, and M the mutual inductance between them; the value of M was read off a calibrated scale. I_2 is the current in the secondary circuit as determined from the deflection θ, and I_1 the corresponding aerial current. This can be calculated from the equation $I_1^2R_i' = I_2^2R_t$, the right-hand side being the actual power dissipated in the heater and the left-hand side its primary equivalent. The last column gives this power P in microwatts.

L_1	L_2	M	θ	R_i'	I_2	I_1	P
μH	μH	μH	mm	ohms	μA	μA	μW
184	211.6	112	42	7.65	37.5	465	1.65
184	1,850	285	65	18.0	46.7	377	2.55
184	1,850	365	75	29.5	50.1	316	2.96
184	1,850	175	24.5	6.77	28.8	379	0.97
1,600	1,850	1,260	31.5	352	32.5	59.5	1.24
1,600	1,850	890	58	176	44.1	114	2.28
1,600	1,850	470	88.5	48.8	54.5	267	3.48
1,600	1,850	228	42	11.54	37.5	377	1.64

Since $I_1 = E/(R_a + R_i')$ where E, the E.M.F. induced in the aerial, and the resistance R_a may be regarded as constants, a straight line should be obtained on plotting $1/I_1$ against R_i'. Fig. 1 shows that although the observations cannot be regarded as very accurate they enable R_a to be determined fairly accurately by producing the line backward to meet the base; the value obtained is about 49 ohms. The ordinates of Fig. 2 represent the power supplied to the heater of the thermo-galvanometer and it is seen that this reaches a maximum of about 3.5 microwatts when the equivalent resistance inserted in the aerial is equal to the equivalent aerial resistance.

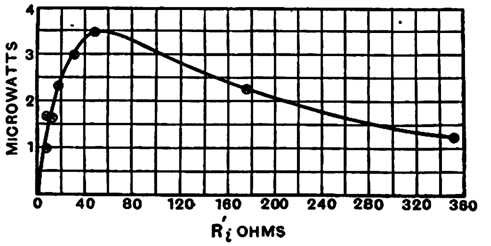


Fig. 2.

Since

$$E=I_1(R_a+R_i')=\frac{R_a+R_i'}{1/I_1}=\text{cotan } a \text{ (Fig. 1)},$$

the E.M.F. induced in the aerial could be determined to a high degree of accuracy; in the present example it was 24.4 millivolts. It must be remembered, however, that, although the current in the Eiffel Tower aerial was always adjusted to 45 amperes, the observations on Fig. 1 were spread over about three hours; the relatively small deviations from the straight line indicate that the transmission conditions remained fairly constant during this period. These measurements were made on the evening of 26th March, the results were worked out and sent to Mr. Duddell on 3rd April, and communicated by him to the Commission at Brussels on 7th April. In a letter Mr. Duddell said: "They created considerable interest as they were the only results in which an actual measurement of the power received in the aerial had been made." We fear that it would be practically impossible to use the same method at the present day, as the receiving aerial was very flatly tuned and susceptible to interference. In 1914 the ether was comparatively empty, and few of the 10-second dashes were missed owing to interference; when it did occur it was usually due to the Admiralty station in Whitehall, and one immediately switched off to prevent the heater of the thermo-galvanometer being burnt out.

The following extract from the Bulletin of the Brussels meeting is of historical interest: " A la fin de la séance, M. Drumaux, dans un exposé remarquable, décrit le renforçateur 'von Lieben-Reiss,' avec lequel il a fait d'intéressants essais, en vue de la résolution du problème de la téléphonie avec fil à grande distance. Cet appareil est certainement appelé à rendre de grands services également en télégraphie sans fil."

This was the thermionic valve amplifier just appearing on the horizon.

G. W. O. H.

A Direct-reading Valve Tester.

By Marcus G. Scroggie, B.Sc., A.M.I.E.E.

It is quite a simple matter, given a generous array of multi-range instruments, to measure the characteristics of a valve. The usual methods, however, are not ideal unless time is no object and great precision is required. There are many circumstances in which a comparatively rough measurement is all that is required, provided it can be performed in a few seconds and without the risk of bad errors due to mental calculation. When this can be done, and with equipment that is not unduly lavish, then the method can be considered useful to those persons who wish to check the characteristics of more than a very few valves.

Before going on to describe an instrument which fulfils these requirements, let us be perfectly clear as to what one wants to measure. The most important characteristic of a valve is the relation between anode current and anode and grid voltages. There are innumerable other characteristics which it would be possible—and doubtless very interesting—to observe, but for rapid tests they cannot be considered. This fundamental relation between the three abovementioned variables is represented graphically by a surface in three dimensions, but as it is not generally convenient to employ a sculptor for the purpose of portraying one's valve characteristics, a quicker but less expressive method is adopted by drawing the profiles of various cross-sections of such a surface, which then appear as the valve curves of commerce. By drawing a number of these curves on a sheet of paper, a clever person is able to fill in the gaps mentally and get quite a clear picture of the electrical behaviour of the valve. If the cross-section is taken at right-angles to the anode voltage axis (which is equivalent to considering the anode voltage to be constant at some amount represented by the distance of the section from the origin of that axis), then the profile of the section takes the familiar form of a grid voltage/anode current curve. Other such curves are formed by taking sections representing other fixed anode voltages. If, on the other hand, the sections are taken at right-angles to the grid voltage axis, then one obtains the outline of anode current/anode voltage curves; a less familiar but more useful type than the previous one. The curves obtained by taking sections at right-angles to the anode current axis are not commonly drawn out, but are indirectly used, as will be explained later.

Though more practical than a solid model, even a set of curves involves some labour, and is out of the question for rapid testing, because even if an automatic curve tracer is used for speeding up the job, it is not always immediately obvious which of two curves refers to the better valve, particularly if they are plotted to different scales. So it has become customary to specify three so-called constants; anode impedance or slope resistance, magnification ratio and mutual conductance. There is an unfortunate lack of standardisation regarding these cumbersome terms and the symbols used to represent them, but in this article they will be referred to as R_a, μ, and G respectively, and the three important variables related in the characteristic surface, namely, anode amperes, anode volts, and grid volts, as i_a, v_a, and v_g.

The three "constants" are in reality very far from being constant for a given valve, a fact which is often obscured when ascribing figures to a particular type of valve. Of the three, μ is the most nearly constant. R_a decreases as v_a and v_g increase; while G, which is not independent but is equal to μ/R_a, consequently increases. A useful amount of information is, however, provided by measuring two of these quantities (from which the third follows) at some known setting of v_a and v_g. The fact that μ is so nearly constant over a wide range of v_a and v_g makes it possible to simplify matters somewhat. The anode current i_a is a function of $(v_a + \mu v_g)$; hence it is convenient to consider the "lumped voltage" $v_l = (v_a + \mu v_g)$, for whatever the values of v_a and v_g, within limits, a given value of v_l will result in very nearly the same values of R_a and G. So it is not necessary to specify all the possible settings of v_a and v_g corresponding to a certain R_a and G; a single v_l covers them all.

It has already been mentioned that there are three main types of valve curves, and the three "constants" are derived one from each of these types. R_a is the slope of the v_a/i_a curve; G is the slope of the i_a/v_g curve, and μ the slope of the v_a/v_g curve. The slopes would, of course, only be constant if these curves were straight lines throughout their lengths, whereas that is far from being the case. It is necessary, therefore, to measure them at the particular points corresponding to the settings at which the valves are to be worked. A valve used as an anode rectifier, for example, has a higher R_a than the same one used as an amplifier, because it is worked at a bend where the slope is less. This makes it necessary to apply some thought to the common cases where the same valve is used for both purposes, and not to fall into the error of applying the figure for R_a measured under normal amplifying conditions to a valve worked at the lower bend.

There are various methods of measuring R_a, μ, and G. The subject offers splendid scope to the theorist for applying the differential calculus, but for practical purposes it is sufficient to measure two points on the curve, one a little below and the other a little above the point of reference, and to assume that the slope of the straight line joining these points is the same as the slope of the curve at the point of reference. An example will make this clear. A valve is to be used as an amplifier with a lumped voltage of 60. To find the R_a at this voltage, the v_a/i_a curve at $v_g = 0$ may be drawn from readings, as in Fig. 1. (Note that it is more usual to plot it as an i_a/v_a curve, which means that the slope has to be considered relative to the ordinate instead of the abscissa). Then R_a is the slope of the tangent to the curve at the point where v_a is 60. On the other hand, it is much quicker and nearly as accurate to measure i_a at 50 and 70 volts and divide the difference in voltage by the difference in current, say, 0.70 mA or 0.0007 amp.

$$R_a = \frac{20}{0{\cdot}0007} = 28{,}600 \text{ ohms}$$

The same applies to the measurement of μ and G. It is obviously not necessary to measure more than two, as the third follows from $\mu = GR_a$. It is also clear that these three quantities are arbitrary, in that one might equally well consider their reciprocals; thus the anode conductance might be used instead of the anode resistance, being the

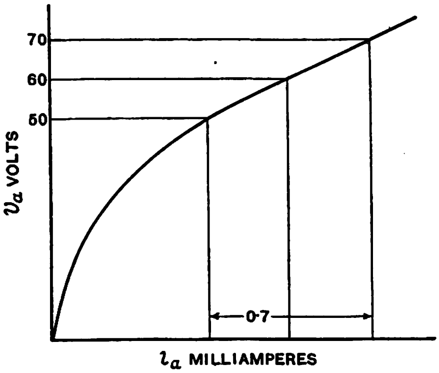


Fig. 1.

slope of the i_a/v_a curve, which is the more usual form for expressing this relation.

The most important of the three for purposes of design is R_a, as it largely determines the correct anode load or amplifier coupling. Of a number of valves equal as regards R_a, the choice then falls on the one having the largest G. A convenient form of test measures R_a primarily and G secondarily; μ may then be derived if desired.

The straightforward test consists, as has just been described, of four readings, two subtractions, and a division. It would be much simpler to boil this down to one reading and no calculations. With a view to exploring this possibility, the i_a and R_a at a fixed v_l of a very large number of valves were measured; valves of almost every type—tungsten, thoriated and coated filaments of 2, 4 and 6 volts; power valves and extra high resistance-coupling valves; old French Rs and LS5A's. R_a and the reciprocal of i_a for all these were plotted on logarithmic paper; three sets of points corresponding to v_l of 50, 100, and 150 volts. Some of the low resistance valves were omitted in the 150-volt set as they showed signs of saturation. As had been hoped, the points in a given set were grouped fairly close to the best straight line through them, and the three lines corresponding to the three sets were practically parallel. The most extreme cases could be covered by a band of about $\pm$ 10 per cent. about the central line, and the majority were much closer. Hence to obtain a measurement of R_a to this accuracy (which is sufficient for most purposes) it is only necessary to measure i_a at the v_l in which one is interested.

An attempt to differentiate between thoriated and coated filaments, and between 2 and 6 volt filaments, did not lead to very definite results, but there are indications that for a given v_a/i_a coated filament valves have a somewhat lower R_a than thoriated.

If V_L is the lumped voltage chosen and I_a the corresponding anode current, then the best lines arrived at experimentally can be defined very closely by the empirical relation

$$R_a = \frac{0.6\ V_L}{I_a}$$

It must be confessed that it was not until an attempt was made to reconstruct the generalised valve curve from this equation that it was realised that the foregoing work amounted to an experimental verification of the familiar expression for the anode current of a valve—

$$i_a = A\ (v_a + \mu v_g)^{\ B} = A v_l^{\ B}$$

where A and B are constants. The latter is often assumed to be 1.5, but has been placed by various investigators at values between 1.5 and 2. It is not in actual fact a constant, but is itself to some extent a function of v_l; hence the disagreement. Assuming our experimental equation, we have

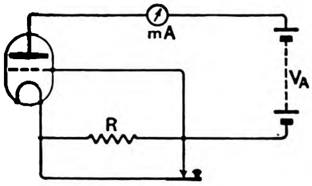


Fig. 2.

$$\frac{dv_l}{di_a} = \frac{0.6v_a}{i_a}$$

and solving $i_a = Cv_a^{\frac{1}{0.6}}$, thus giving an index for average valves of 1.67. This result, though perhaps outside the scope of this article, has been included as being of some general interest.

The general scheme of an instrument for giving direct readings of R_a on these lines is obvious, and a convenient practical arrangement will be described shortly, but in the meantime let us consider an extension of the method for the purpose of indicating G also. It would be possible to provide means for impressing a known negative bias on the grid of the valve (which has been held at zero potential for the measurement of R_a), say one volt, and the resulting drop in anode current would be a measure of G. This method necessitates a voltmeter for ensuring that the correct bias is applied, and also a special biasing battery. Both these extras are dispensed with by utilising the principle of automatic grid bias, which also carries with it the important advantage that the amount of the bias is always suited to the type of valve being tested. The principle of this method is illustrated in

Fig. 2, where a resistance R, which is normally short-circuited by a push-button switch is shown interposed between negative H.T. and filament. The grid of the valve is connected to negative H.T. A milliammeter indicates the anode current at zero grid potential, and can if desired be made to read R_a direct in ohms. A better method will be described further on. If now the push-button be pressed, putting R in circuit, the grid will be biased negatively, and the anode current will consequently be reduced. The drop in current is related to the G of the valve, as will now be shown. Let I_1 be the anode current with the resistance R shorted, and consequently with an anode voltage V_a (say) and a grid voltage of zero. When the resistance R is inserted, the current falls to I_2 and the anode voltage is then $V_a - I_2R$ and the grid voltage is $-I_2R$. Now, from the definition of μ it follows that the drop in anode volts I_2R is equivalent to a drop in grid volts of I_2R/μ. The effect, therefore, is the same as that due to a grid voltage of $-I_2R\,(1 + 1/\mu)$, the anode voltage being maintained at V_a. G is defined as the change in anode current divided by the change in grid voltage responsible, at constant anode voltage. (To the mathematician this is an inexcusably loose statement, as it only gives a rough average over a portion of the characteristic curve instead of the more elegant $\frac{di_a}{dv_g}$, but is nevertheless well suited to practical requirements).

$$
\begin{aligned}
\text{Thus } G &= (I_1 - I_2)/I_2R\,(1 + 1/\mu) \\
&= (I_1 - I_2)/I_2R\,(1 + 1/GR_a) \\
1 &= (I_1 - I_2)/I_2R\,(G + 1/R_a) \\
\text{and } G &= \frac{I_1 - I_2}{I_2R} - \frac{1}{R_a}
\end{aligned}
$$

If $1/R_a$ is neglected and the milliammeter (Fig. 2) is controlled by a variable shunt, so that for every valve the needle is brought to a fixed mark by the current I_1, then the scale can be marked off to read G directly when the button is pressed. For example, if R is 1,000 ohms and on pressing the button the current is reduced to two-thirds of the original value, then $G = 1/2{,}000$, or in more usual units 0.5 milliamps per volt. A table can be drawn up in this way connecting $(I_1 - I_2)/I_2R$ and G, and the instrument calibrated accordingly. The error due to the neglect of $1/R_a$ obviously is most serious when R_a is small. Thus if in the above example, R_a is 4,000 ohms, the correct value of G is only 0.25 mA per volt. As R_a is presumed to be already measured, it is not a difficult matter to make this correction.

Having now discussed the matter theoretically, a practical form of apparatus will be described in which the foregoing calculations are made absurdly simple. The gear involves only one measuring instrument, apart from any that may be used for testing filament consumption, etc. The circuit diagram is shown in Fig. 3, and the numerical values of the components are those suitable for testing almost any type of receiving valve, ancient or modern. V and A are low consumption meters, Weston type 301 reading up to 6 volts and 1 ampere respectively for setting to the correct voltage and checking the current. The filament rheostat R_2 is of the Burndept dual type with a graded element; maximum resistance 60 ohms. mA is a milliammeter reading up to 1 mA full scale when the potentiometer shunt R_3 is at its maximum. It can easily be shown that when connected as illustrated the full scale current of the meter is inversely proportional to the resistance to the left of the slider, and hence if the resistance is uniformly wound the scale of the shunt when calibrated to read R_a direct in ohms is linear. "Full scale" need not necessarily be what is usually understood by that term, but any convenient mark. Thus Fig. 4 shows a suitable form of calibration for the meter and shunt. The latter is a Burndept rotary potentiometer uniform with the filament rheostat, especially wound to 64

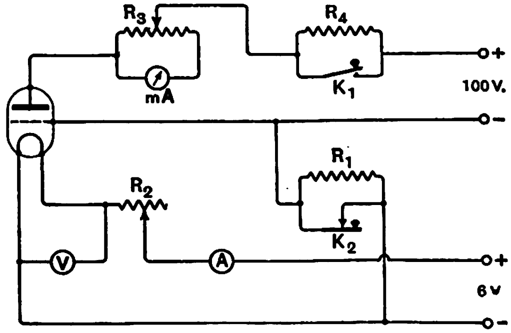


Fig. 3.

ohms, and is calibrated 0–60,000 ohms. The outer concentric scale is the reciprocal of the inner, so gives the correction to be subtracted from the value of G indicated by the meter. When the shunt is adjusted so that the milliammeter needle is brought to the prominent mark towards the right of the scale, then R_a can be read off directly in ohms. The procedure in testing a valve is first to adjust the filament to the correct voltage; then if the valve is to be tested for normality the shunt is set to the normal R_a (the scale may be marked with the names of various types of valves according to this value), and the pointer indicates the variation from normal. Before actually taking the reading the safety resistance R_4 is shorted out by the key K_1, after it has been noted that the anode of the valve is not touching the grid or filament, which would be indicated by an unduly high reading on the milliammeter. The needle is then brought to the central mark (the shunt pointer then reads actual R_a) and the key K_2 pressed, putting resistance R_1 of 1,000 ohms into action. The needle of the milliammeter will then take up a new position indicating G on the lower scale. Finally this value of G is corrected by subtracting from it the amount indicated by the pointer of the shunt. It will be noted that a disconnection or misconnection of any of the elements of the valve will be shown up by one or other of these tests. μ if desired is obtained by multiplying R_a and G already found, being, of course, in *amperes* per volt for this purpose.

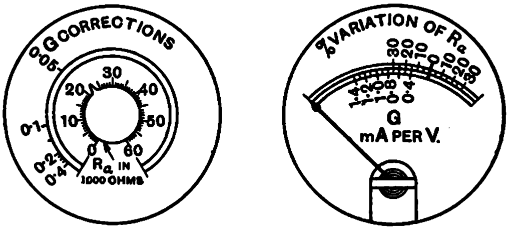


Fig. 4.

A little refinement that is useful concerns the value of R_4. The accuracy of the instrument obviously depends on the anode battery being maintained at 100 volts (or whatever figure is chosen). R_4 is therefore made of such a value that with anode and filament valve sockets joined and shunt slider at maximum (right), the milliammeter reads full scale, or any convenient mark, when the battery is correct. It is inadvisable to press K_1 when making this preliminary test.

It is possible for a relatively unskilled operator to test valves very rapidly using this apparatus, which is not by any means costly, and its convenience outweighs, for many purposes, its limitations as regards accuracy. For example, if it is desired to pick a particularly good valve out of a dozen samples, it would be quite tedious to do so by the more usual methods. Or if one does a large amount of experimental work with apparatus involving valves, it is extremely irritating to find one's results vitiated by the presence of a valve past its prime. The test-gear just described is so rapid that it is no hardship to make a practice of testing all valves before each experiment. The details of construction may, of course, be adapted to the particular requirements of the situation.

Loop Permeability in Iron, and the Optimum Air Gap in an Iron Choke with D.C. Excitation.

By A. A. Symonds, M.A.

I.

LOOP PERMEABILITY.

In view of the frequent use of iron-cored chokes and transformers with a direct current through the winding, there seems some need for considering the appropriate properties of iron used in such instruments.

As explained in a recent Editorial,* when, in addition to the applied alternating fluctuations, there is a direct current through the winding producing a constant flux through the core, a cyclic curve representing the alternating fluxes must be drawn about some point on the *B*—*H* diagram given by the magnetic condition of the iron.

This part of the paper is concerned with the property of the iron when there is a direct current maintaining a constant *H* in the iron. The complete solution of the problem requires knowledge of all the cyclic curves and local loops in the iron over the range of operation, and the previous history of the iron with respect to the D.C. component of induction, and, in addition, the phase and magnitude of the A.C. component. This is not attempted. The problem is limited by taking the D.C. component of induction as being defined by the reversal curve for the iron, and the amplitude of the alternating component of induction, denoted here by δB, as being considerably smaller than the D.C. component. In the experimental work to be described the R.M.S. value of δB never exceeded 20 per cent. of the D.C. induction.* With values of δB nearly equal to or larger than the D.C. component of induction, extraordinarily shaped curves occur,† but these are not dealt with here.

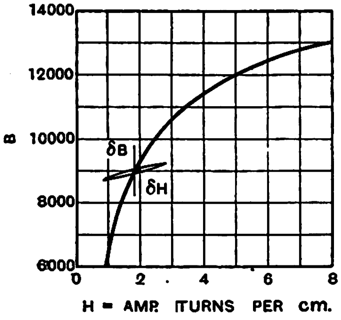


Fig. 1.

Ewing has shown‡ that loops of the sort we are dealing with are always lenticular in shape, very narrow, and materially independent of the frequency, and that their mean slope is far less than the slope of the reversal curve at the point where they are taken. Also the form of the loops assumed for relatively small amplitudes of δB is nearly obliquely symmetrical with respect to local axes of B and H, see Fig. 1, so that if δB is a simple harmonic variation of induction with time, then the corresponding variations of magnetic force, δH, will have only odd harmonics, and one can assume that the current is a simple harmonic function of time with a maximum given by the appropriate value of δH. Thus to a degree of accuracy which the above simplification allows, the only important quantity is the slope of the major axis of the loop, $\delta B/\delta H$. This is the loop or incremental permeability of the iron, and is written μ'.

With this view of the loops they will appear to differ only in the slope of their axes, and as is shown by Ewing,‡ this decreases from a maximum in the neighbourhood of $B = 5{,}000$ lines per cm.^{2} roughly as the slope of the reversal curve decreases. Below this value of B μ decreases, and μ' is certain to decrease also, for it is obvious that if δB is considerably smaller than B, μ' cannot be greater than μ. No quantitative measurements were, however, made at these low inductions. Spooner has given a method of calculating μ' very approximately,* and a few experimental figures† ; but his method of measuring $\delta B/\delta H$ is complicated by other objects in view, and the accuracy attempted is not great.

---

* *E.W. & W.E.*, Feb., 1928.

* The experimental work was carried out at the Cambridge University Engineering Laboratories.

† "Hysteresis Loss in Iron taken Through Unsymmetrical Cycles of Constant Amplitude," M. Rosenbaum, *J.I.E.E.*, Vol. 48, pp. 534–545.

‡ "Magnetic Induction in Iron and Other Metals," by J. E. Ewing, 3rd Ed., Sections 77 and 78.

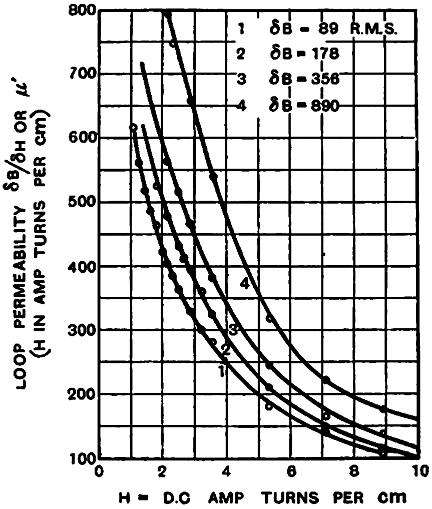


Fig. 2a.

In connection with the above simplification it is interesting to note that the slope of the axes of local loops is not much changed when the induction in the iron is very far from being defined by the reversal curve. In the experiment to be described a reading for μ' was taken for a certain value of D.C. induction which, since the iron had been demagnetised by reversals, would be as defined by the reversal curve. The direct current was then increased by 50 per cent. and reduced again to its original value, and the resulting μ' was inappreciably changed when the induction for which the measurements were made was less than 11,000 lines per cm.[2] Since the moment of closing, the switch, and hence the transient conditions of current, had no apparent effect on μ', it is reasonable to suppose that the A.C. loops in the iron do not follow any rigorously defined paths till after some cycles of A.C., and in evidence of this is the fact that the mean slope of a small change of induction varies, falling off in value after the first change till it finally takes up some constant value. T. Spooner has given quantitative measurements of this falling off in value of μ', showing the change to be some 20 per cent., and to become constant after about 50 cycles. Thus $\delta B/\delta H$ has different values—one for the case of a single reversal of a small current and another for the case of a continuously applied A.C.

The values of $\delta B/\delta H$ for Stalloy, with the meaning and limitations already discussed, are given in curves in Fig. 2, (*a*) and (*b*), where, to facilitate their use in practical design, the units of magnetic force used are ampere turns per cm. of iron. These units are used in the curves throughout the paper ; the change to absolute units is easy as one has only to use the factor $4\pi/10$.

The loop reluctivity ρ' corresponding to the loop permeability μ' is shown in Fig. 3.

These curves were taken by measuring the alternating current necessary to produce a selected virtual voltage across the terminals of a transformer, through one winding of which a known direct current C was passing. The circuit used is shown in Fig. 4.

The iron was 27.9 cm. in length and 4.97 cm.[2] in cross section. Two windings were employed, a primary of 1,000 turns and a secondary of 200 turns, tapped at convenient stages.

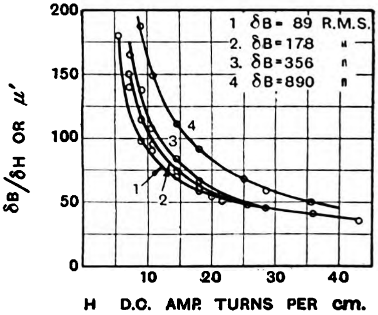


Fig. 2b.

A winding of sufficient section to carry both the alternating and direct currents necessarily occupied a considerable space. When there is a direct current in the winding $\delta B/\delta H$ is not very large, so that the inductance is appreciably affected by stray fluxes, and thus it was necessary to measure the fixed alternating P.D. (V_2, Fig. 4) across a separate secondary. This secondary was wound as close to the iron as possible.

---

* *J.Am.I.E.E.*, 1923, pp. 42–47.

† *Physical Review*, 1925, pp. 527–539.

TABLE A.

Showing the method of deriving $\delta B/\delta H$ from experimental data.

C	V_2	N_2	δB	R	V_1	δI	$\delta(IN/l)$	CN/l	$\mu' = \frac{\delta B}{\delta H}$	μ'' (see note)
.1	1	40	890	21.3	.96	.0451	1.61	3.58	552	440

NOTE.—In the last column but one, as throughout this paper, δH is in ampere-turns per cm.; in the last column μ'' gives the corresponding value if δH is in the usual absolute units.

The value of the alternating current δI producing the δH was obtained by measuring the voltage across a known resistance R by means of a thermionic voltmeter V, a condenser of 4 μF. capacity being included in the circuit to exclude the D.C. drop across R.

A D.C. ammeter, as shown at C, and a reversing switch (not shown) for the purpose of removing residual magnetism from the iron when so desired, were included.

The D.C. ampere turns per cm. in the primary of 1,000 turns are known, and δB was obtained from V_2 since we have,

$$V_2 = A\,\delta B\,N_2\,2\pi n \times 10^{-8},$$

where A = cross section of the iron,

and n = cycles per sec.

Table A gives a sample of the reduction of results, where the experimental readings were collected and the conversion to $\delta B/\delta H$ carried out. The A.C. supply was at 90 cycles.

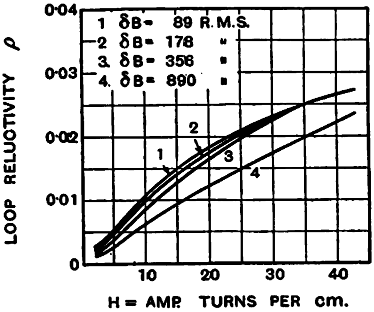


Fig. 3.

The values of δB given in the curves I, II, III, and IV correspond to selected applied E.M.F.'s of .56, 1.12, 2.2 and 5.6 volts R.M.S. per 1,000 turns per cm.^{2} of iron cross section, at 100 cycles. This method of giving the results provides a convenient means of determining the δB that will occur for any given values of dimensions, turns, applied E.M.F. and frequency.

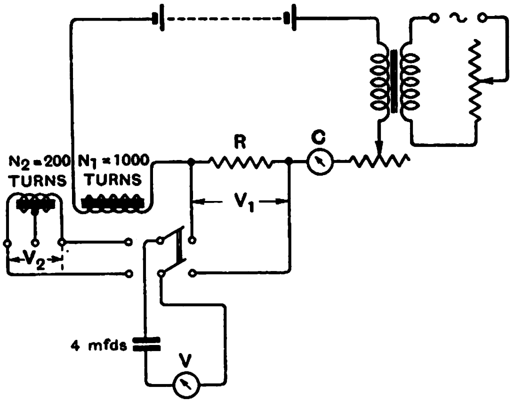


Fig. 4.

II.

THE OPTIMUM AIR GAP.

It will be seen from Fig. 2 how μ' decreases as the D.C. excitation increases, and this explains the falling off in inductance of iron cored chokes and transformers, as is shown in a paper recently published by L. B. Turner.* It is the object of this part of the present paper to consider the application of the experimentally determined specific properties of the iron in the determination of the optimum air gap for a core, and the value of the consequent inductance. This inductance will be the maximum obtainable from the iron core for the assigned conditions of turns and direct current. Conversely, given any fixed direct current, the number of turns for any required inductance can be found, and the correct air gap.*

---

* "Measurement of a Stalloy Core with D.C. and A.C. Excitation," L. B. Turner, *E.W. & W.E.*, Oct., 1927.

Suppose we apply a direct current to an iron cored choke with a small air gap cut in the iron. Consider any fixed value of induction B throughout the magnetic circuit; we have,

$$M = H_i l + Ba$$

where M = the M.M.F. required.
H_i = the magnetic force in the iron.
l = the length of the iron.
a = the length of the air gap.

H_i is given by the reversal curve for the iron for the value of B considered, so that the consequent loop reluctance of Stalloy with this induction can be found from Fig. 3. Thus for a change of induction δB,

$$\delta M = \rho' l \delta B + a \delta B$$

and hence, writing $M/l = m$,

$$\delta B/\delta m = 1/(\rho' + a/l) \quad .. \quad .. \quad (1)$$

This $\delta B/\delta m$ obviously depends on the value of m, and curves between $\delta B/\delta m$ and m are shown in Fig. 5 for various constant ratios of air gap length to iron length a/l. These curves are obtained by the use of Fig. 3 and equation (1), since for any B we know the value of H_i from the reversal curve. As would be expected, these curves begin more or less flattened at low values of m when the loop reluctance in the iron will be small and the constant air gap reluctance relatively large.

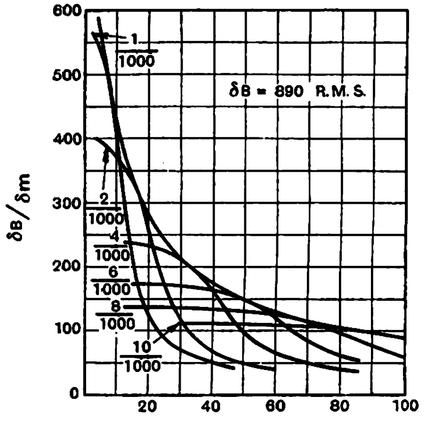


Fig. 5.

Considering any constant m, Fig. 5 shows what value $\delta B/\delta m$ will have for any of the air gap ratios for which curves are drawn, and by drawing the envelope to the curves shown in Fig. 5 we get a derived curve showing the maximum $\delta B/\delta m$ that it is possible to obtain for any given m.

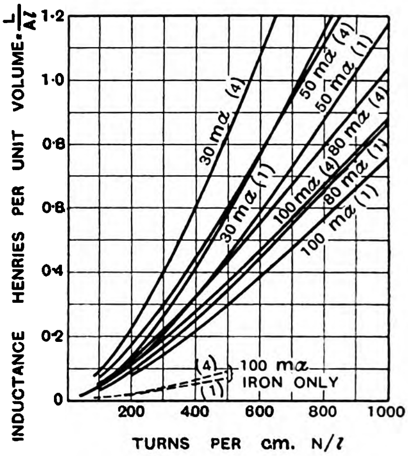


Fig. 6a.

Curves (1), $\delta B = 89$ *R.M.S. lines per cm.*^{2}
Curves (4), $\delta B = 890$ *R.M.S. lines per cm.*^{2}

On the assumptions made with regard to local loops on the $B-H$ curve we can define the inductance of a coil with an iron core as the rate of change of flux turns with current.

$$L = d(\phi N)/dI$$

so that for a composite iron and air gap core

$$L = Al\frac{N^2}{l}\,\delta B/\delta m \times 10^{-8} \text{ henries} \quad .. \quad (2)$$

where A = cross-section of the core.
N = total number of turns.
m = M.M.F. per cm. of magnetic circuit length, in amp. turns per cm. units.

Now with the aid of the envelope of Fig. 5, obtained for the appropriate value of δB, it is a simple matter to take any constant direct current and with the help of (2) to plot inductance per unit area of cross-section and length of core, against number of turns per cm., for Stalloy. This is done in Fig. 6 (*a*) and (*b*) for cases where $\delta B = 89$ and 890, for a number of direct currents between 10 and 100 mA.

---

* The method employed for obtaining the maximum $\delta B/\delta H$ is similar to one given in the Editorial, *loc. cit.*, from a paper, "The Design of Reactances and Transformers with Superposed D.C.," C. R. Hanna, *J.Am.I.E.E.*, Feb., 1927.

In Fig. 5 any point where one of the curves touches the envelope is a point of maximum possible $\delta B/\delta m$. Thus from Fig. 5 can be derived a curve connecting air gap ratio a/l and m. This curve is shown in Fig. 7 for $\delta B = 89$ curve I, and for $\delta B = 890$ curve IV.

It can be seen from the curves of Fig. 5 that the loss of inductance due to an air gap ratio erring on the large side is less than the loss due to an air gap ratio erring on the small side. For instance, in Fig. 5 take the point where $m = 52$ amp. turns per cm. The maximum $\delta B/\delta m$ given by the envelope is 143, and this for an air gap ratio 6/1,000. If the ratio had been 8/1,000 $\delta B/\delta m$ would have been 129, whereas if the ratio used had been 4/1,000 the $\delta B/\delta m$ would have been 89.

So far only constant known applied A.C. voltages have been considered, which is by no means likely to be the only practical condition; in fact, this case seems to be confined to A.C. rectifiers designed for a constant output.

If instead of plotting $\delta B/\delta m$ against m, as in Fig. 5, we plot $\delta B/\delta m$ against B, we get another series of curves, each curve being drawn for a particular ratio a/l. Selecting a value for B we can compare the $\delta B/\delta m$ obtained with this B and some particular air gap ratio, as found from this curve, with the maximum $\delta B/\delta m$ shown in Fig. 5 for the value of m giving the selected B, and thus we can find the diminution of $\delta B/\delta m$ resulting from using conditions other than the optimum. By this means an air gap cut to allow an induction of 9,000 lines throughout the core will be found to cause a diminution of possible $\delta B/\delta m$ of only 9 per cent. over the range of D.C. excitation and applied voltages considered here. This is about the best average value possible and should be used whenever the applied A.C. volts are known to vary in amplitude or frequency to any considerable extent.

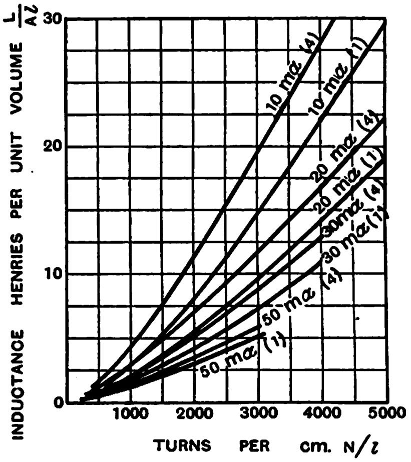


Fig. 6b.

Curves (1), $\delta B = 89$ *R.M.S. lines per cm.*^{2}
Curves (4), $\delta B = 890$ *R.M.S. lines per cm.*^{2}

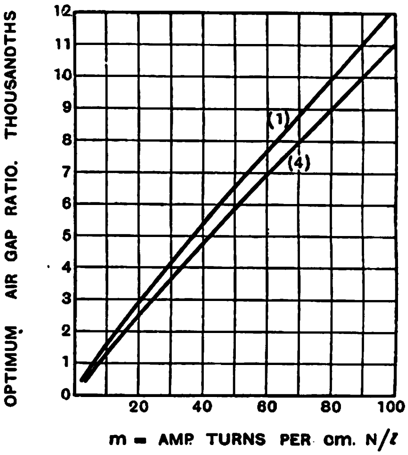


Fig. 7.

Curves (1), $\delta B = 89$ *R.M.S. lines per cm.*^{2}
Curves (4), $\delta B = 890$ *R.M.S. lines per cm.*^{2}

The stray flux is now an important consideration. Most of the stray flux is in the neighbourhood of the air gap, and the effect of this is to reduce the effective reluctance of the air gap.

Consider an air gap of length a'. Let a be the length of the air gap which, with no stray flux, would have the same reluctance as the gap a'. Let q be the dispersion coefficient. Then, since the flux crossing the gap a is the same as the flux crossing the gap a' plus the stray flux,

$$qa = a' \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

The dispersion coefficient depends on the configuration of the iron, and on the air gap, and its value is best found experimentally. Two specimens of the iron core to be used, made up with different air gaps of about the expected length, will give a short curve between q and a', by means of which, with the aid of equation (3), a graphical solution for q is obvious.

An example of the use of the curves follows.

A smoothing choke was required for an A.C. rectifier giving 60 mA. D.C. at full load output. Considerations of ohmic drop and space available for winding led to 8,100 turns being the maximum that could be wound on the core, 28 cm. long and 5.6 cm.^{2} in cross-section. The A.C. fluctuations were calculated to produce 40 volts R.M.S. across the choke at full load, the worst conditions, and at 100 cycles. The corresponding δB in the iron will be 78, for which curves (1) will be near enough.

The D.C. excitation is $\frac{.06 \times 8{,}100}{28} = 17.4$ amp. turns per cm.

From Fig. 6 (*a*) curve (1) for 50 mA. and 290 turns per cm. the inductance is .20 H. per unit cross-section and length. For 80 mA. the inductance is .16 H. For 60 mA., therefore, the inductance will be approximately .19 H. Hence the inductance of the choke should be $.19 \times 28 \times 5.6 = 29.8$ H., and from Fig. 7 curve (1) the optimum air gap ratio for 17.4 amp. turns per cm. is 2.5/1,000, hence the air gap length should be $28 \times 2.5/1{,}000$ cm. = .7 mm.

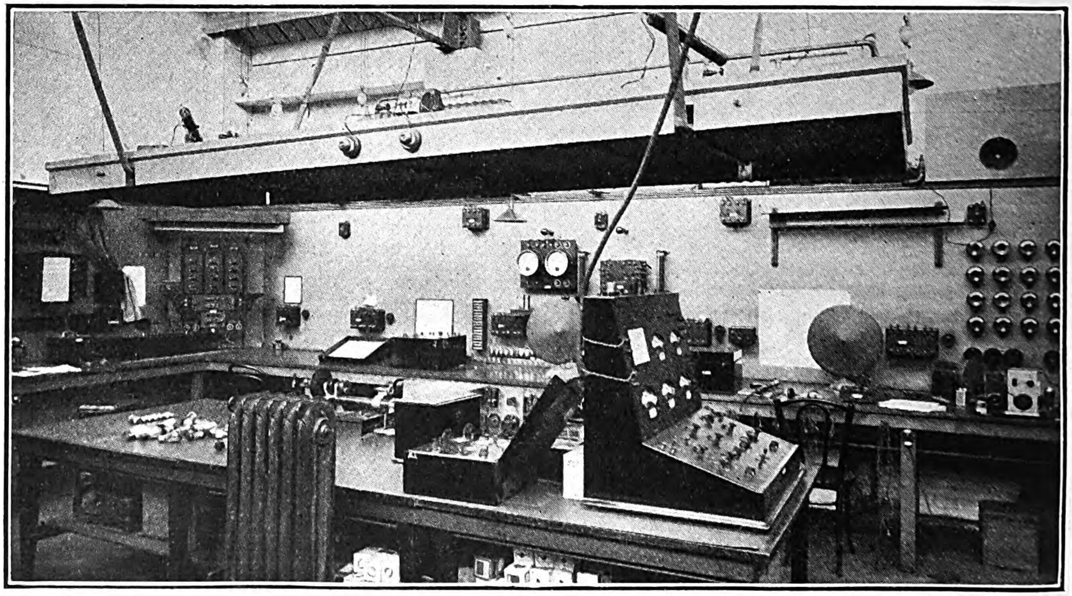
The dispersion coefficient for the iron core was 1.41, and since the equivalent air gap a required is .7 mm. we have from equation (3) that $a' = .99$ mm. This is the air gap to be cut in the iron core.

With the object of comparing actual with predicted results an applied voltage was adjusted to give a δB of 78, and the inductance measured. This was found to be 31.2 H. The winding itself had a small inductance of about 1 H. not associated with the iron core, and this added to the predicted inductance gives 30.8 H., which should be compared with the actual inductance of 31.2 H.

The close tallying of the predicted with actual figures is, no doubt, partly fortuitous, as in fact the actual air gap was 1.5 per cent. smaller than specified; but the figures show the practical utility of the method.

With a plain iron core and no air gap, the nductance of the choke would have been 6.8 H., from which it can be seen that the gain in inductance due to suitable air gap is nearly 400 per cent.

I have been privileged in having the kind assistance of Mr. L. B. Turner in the preparation of this paper.



A view of the Burndept research laboratory. A valve-testing set is seen on the right. The platform over the bench is mounted on rubber cushions and carries a mirror galvanometer.

Some Output Power Measurements on a Moving Coil Drive Loud Speaker.

By H. A. Clark and N. R. Bligh.

1. Introduction.

DURING the course of some experimental work in which a moving coil cone loud speaker was employed the instrument was suspected of having a very pronounced resonance at a low frequency. Some measurements were made therefore at these frequencies. It was also decided to make a complete test on the instrument over the acoustical range.

Owing to the increasing use of this type of reproducer it is thought that the results and the method of obtaining them will be of general interest, particularly by showing, as they do, the weak points in the design of this particular instrument.

2. Description of Loud Speaker.

The instrument on which the measurements were made is representative of a large number now in use. It consists of a 7in. diameter right-angled conical diaphragm of stiff drawing paper varnished to prevent moisture absorption and carrying a moving coil wound on an extremely thin ebonite former. The diaphragm is suspended at its periphery only by means of a ½in. width of oiled silk attached to a wooden ring which is screwed to a vertical wooden panel containing a 7⅜in. circular opening. The coil is free to move in a ⅛in. annular gap in the usual form of cylindrical field magnet excited by 0.6 ampere at 6 volts.

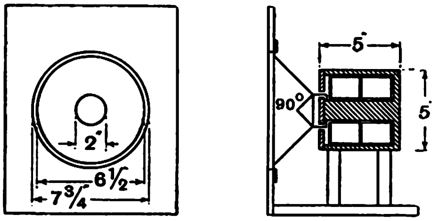


Fig. 1.—*Illustrating type of loud speaker on which measurements were made.*

The moving coil consists of 100 turns of No. 38 S.W.G. enamelled copper wire, the leads being brought down the diaphragm to the edge, where they are joined by a pair of spiral fine wire leads to the input terminals. The instrument was used with a 6ft. square baffle.

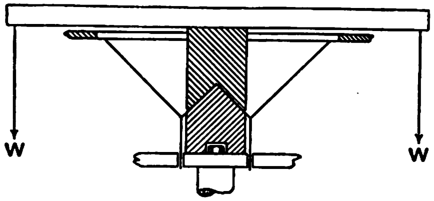


Fig. 2.—*Method of clamping diaphragm.*

Measurements Required.

It was required to find the resistance and reactance of the instrument over the audible range of frequencies both with the loud speaker in its normal operating condition and also with the diaphragm rigidly clamped in order that the acoustical output may be reduced to zero. In doing this care has to be taken that the moving coil remains in the same position as when the diaphragm is free to move. It was found that the most satisfactory method of ascertaining this was to use a pair of wooden cylinders, one having an external cone and the other an internal cone turned on their ends to fit the re-entrant cone of the diaphragm perfectly and of such a diameter that one will just enter the former of the moving coil. Its length must be such that when resting on the surface of the pole piece of the field magnet the diaphragm is closely in contact with it when the moving coil is in the correct position. A recess must be made to accommodate the bolt head securing the pole piece. When the inner cone was thus fitted the instrument was arranged with its axis vertical and then the upper cone put in position. A cross bar of wood was laid across the end of this and weights hung from the ends to hold the diaphragm perfectly rigid. A total of 8 lbs. was found sufficient. It is important to note that the connection between the coil and the diaphragm must be sufficiently rigid to prevent the former moving independently of the latter.

3. Principle of Method.

As the reactance to be measured may change from positive to negative at some frequencies, a method of measurement in which this may be accommodated without change in circuit connections, etc., was required. The Heaviside equal ratio inductance bridge was therefore decided upon. This is illustrated in the accompanying schematic diagram (Fig. 3).

R_1 and R_2 are two identical resistances. R is a variable known resistance of very low or known inductance. M is a variable standard of mutual inductance.

The apparatus under test is put in circuit at will at X. The bridge is supplied at *ac* with an alternating voltage and some form of detecting device placed across the points *bd*.

Now suppose X to be short-circuited and that the bridge is balanced with settings of M' and R' respectively on the mutual inductometer and R. Now let X be put in circuit and the bridge rebalanced to give values of M'' and R''. Then it may be easily shown that the inductance added at $X = L = 2(M'' - M') + \theta$, where θ is a small correction due to unbalanced residual reactances in the balance arm and due to the reactance of the resistance R, and the resistance added at $X = r = R'' - R' + 2\rho'' - 2\rho' + \theta'$, where ρ is an impurity in the mutual inductance and is due to an E.M.F. induced in phase with the primary current and θ' is an error due to inequality in the bridge arms which can be eliminated by interchanging them.

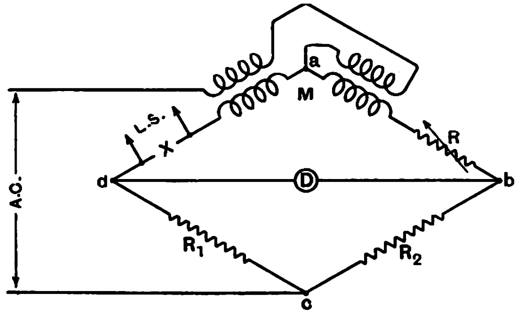


Fig. 3.—*Theoretical Circuit of Bridge.*

Now, for the order of accuracy required in this work both the impurity of the mutual inductance and the reactance of the resistance R may be neglected, giving the simple results

$$L = 2(M'' - M')$$

and $$r = R'' - R'.$$

If now the effective inductance L becomes negative, the arm of the mutual inductometer will swing on to the negative part of the scale. For large negative values it is only necessary to reverse the connections to the primary of the inductometer.

4. Practical Arrangement of Apparatus.

In practice a number of additions were required to the simple bridge circuit shown above. To render the arrangement sensitive a two-stage amplifier was used at the output terminals to supply a pair of telephones in which the balance of the bridge was judged. It was found desirable to earth the bridge at the point C and also to enclose the resistances R_1 and R_2 in earthed screens to reduce direct pick-up. The source of AC and the amplifier were also earthed, and to prevent throwing large capacity loads across the bridge screened and balanced transformers were used for both input and output. Owing to the fact that the mutual inductometer was not screened, it caused considerable pick-up by induction. As screening would probably alter the calibration rather seriously this was put at some feet from the rest of the apparatus. The inductance and capacity of the leads are of no moment as they produce an error which cancels out owing to the difference method explained above.

The loud speaker was put in an adjoining room owing to the acoustical output making balancing in the telephones difficult. The inductance of the long flex leads produces another error which cancels out as the short-circuiting device was put at the loud speaker terminals. This consisted of a copper link making contact in mercury pools in a block of paraffin wax.

For frequencies above 200 cycles per second a valve oscillator was used. This was of the ordinary feed-back type, and produced a reasonably good wave-form. The amount of harmonics present was not sufficient to render balance difficult. The whole oscillator was placed in a heavy brass screen which was earthed. To measure the frequency a Campbell frequency bridge was used.

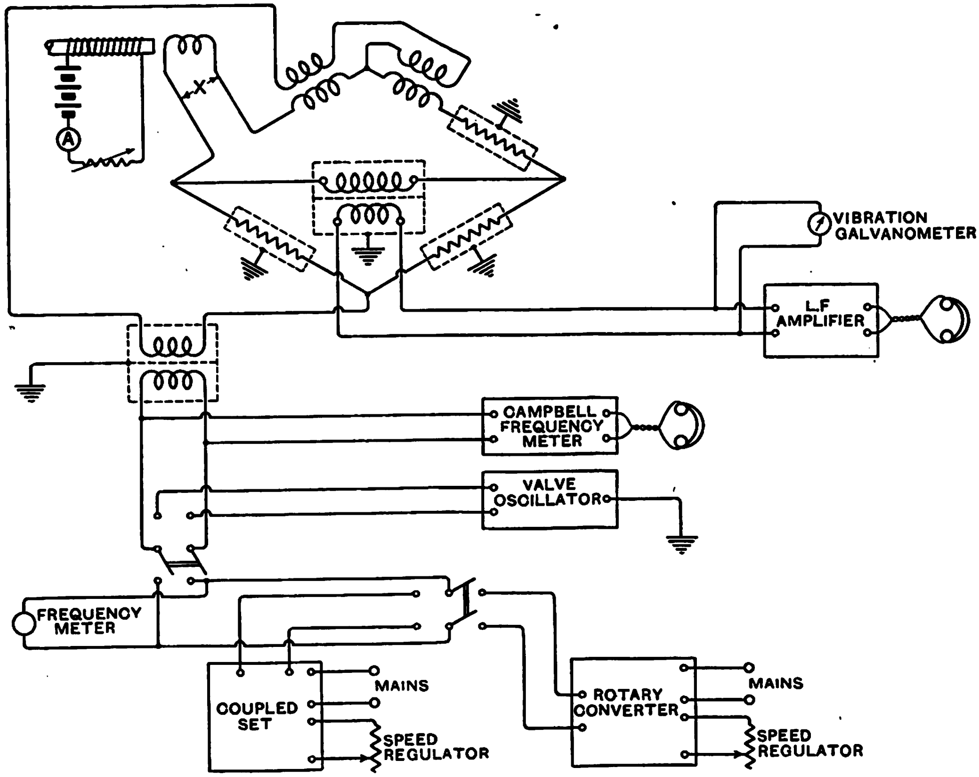


Fig. 4.—*Practical Arrangement of Apparatus.*

Below 200 cycles the oscillator was unsatisfactory as the output at the fundamental frequency was found to decrease considerably, also aural balancing was found to be of increasing difficulty. The supply was therefore taken from a coupled set consisting of a D.C. shunt motor with a field regulator for speed variation and a single phase alternator with a transformer with a number of tappings for various voltages.

A Campbell type of vibration galvanometer was used as a detector below 200 cycles. The amplifier was also left connected, however, and it is interesting to note that quite a fair degree of accuracy could be obtained by aural balancing as low as 70 to 80 cycles. It should be mentioned that high-class components were used in the amplifier to enable this to be done. Greater accuracy was obtainable, however, with the galvanometer. The only disadvantage of this instrument for this type of work is that it has to be tuned for every frequency used; this is a tedious operation when numerous readings are required.

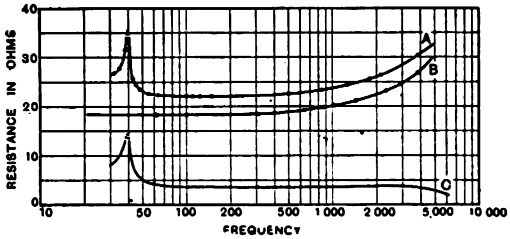


Fig. 5.—*Curve A—Resistance with diaphragm free. Curve B—Resistance with diaphragm clamped. Curve C—Motional Resistance.*

The frequency was read on a direct reading frequency meter by the Weston Electric Instrument Co. Below 60 cycles the coupled set had to be run at such a slow speed that the frequency was not constant. A rotary-convertor capable of covering a range of 30 to 60 cycles was therefore used, together with an L. C. Wild type of direct-reading frequency meter, made by R. W. Paul. On these very low frequencies the Campbell galvanometer was found to be unsatisfactory and a Drysdale type, by Tinsley, was substituted. As will be seen from the results which follow it was of the greatest importance to keep the frequency very constant while taking measurements at low frequencies. The complete layout of apparatus is shown in Fig. 4.

5. Experimental Results.

The figures obtained for the effective resistance both for clamped and free diaphragm have been plotted and are shown in Fig. 5. The difference between these is due to the acoustical work done* and is represented by so many ohms. The reactance has also been plotted as found by taking $2\pi f$ times the effective inductance. It is quite obvious that the suspicions entertained were justified. A very sharp resonance was undoubtedly present at about 40 cycles.

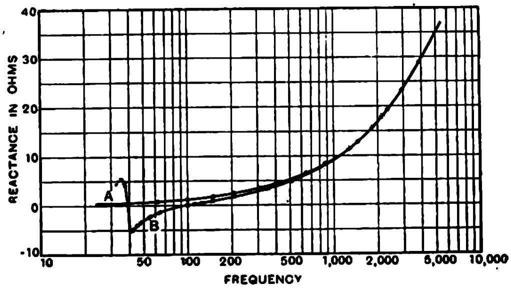


Fig. 6.—*A—Reactance diaphragm clamped. B—Reactance diaphragm free.*

Now, the power in any circuit is given by the effective resistance multiplied by the square of the current in the resistance. Hence, if the current through the moving coil = I amp. (R.M.S.) and effective resistance with the diaphragm free = R_1 ohms, then the total power supplied to the loud speaker = I^2R_1.

If the resistance with diaphragm clamped = R_2 ohms, then the output or acoustical radiated power = $I^2(R_1 - R_2)$, assuming no losses in moving the diaphragm other than the load produced by the air.

Hence, if the current through the moving coil were constant at all frequencies, the output power characteristic would have the shape shown by the output resistance curve.

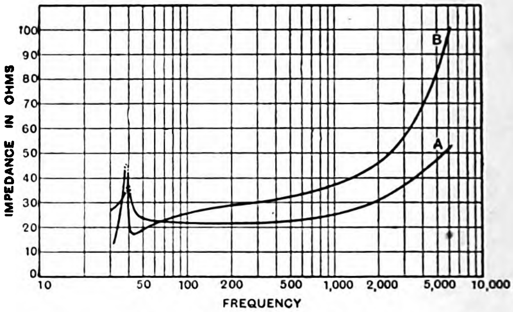


Fig. 7.—*A—Impedance of loud speaker alone. B—Impedance of loud speaker, transformer and valve.*

This, however, is not the case. Assuming a constant voltage across the loud speaker terminals, the current will vary inversely as the impedance. Now both the effective resistance and reactance vary very largely with frequency, and hence the output will vary within very wide limits.

The impedance of the loud speaker at various frequencies has been calculated from the resistance and reactance figures. This is shown in Fig. 7. Assuming a constant voltage supply, the current and hence output power can be calculated. The curve shows that the output power varies from 13.3 per cent. at 6,000 cycles to 230 per cent. at 40 cycles, taking the power at 100 cycles at 100 per cent.

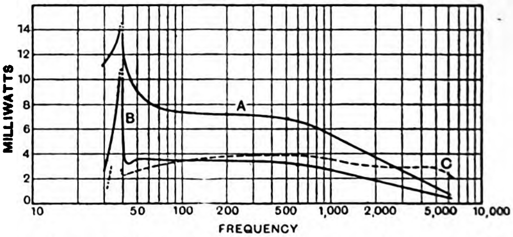


Fig. 8.—*A—Output for* 1 *volt across loud speaker. B—Output for* 24 *volts across primary of transformer. C—Overall characteristic for loud speaker and amplifier.*

Neglecting small iron and eddy current losses, the force on the diaphragm will be in phase with the current. The phase of the current relative to the E.M.F. across the terminals can be calculated, and hence the "phase distortion" of the loud speaker can be found.

---

* *See* Appendix.

6. Effect of Step-down Transformers and Valve Impedance.

In actual practice the loud speaker is used in conjunction with a step-down transformer the primary of which is in the anode circuit of the output valve of an amplifier. It can be shown that this transformer has a very considerable influence on the performance of the loud speaker. The constants of the transformer being known, it is possible to calculate its effect at any frequency by using an equivalent circuit. This equivalent circuit is shown in Fig. 9.

The values for the step-down transformer normally used with the loud speaker are as below :—

Primary inductance with normal polarising current (L_1) = 25 henries.

Equivalent self-capacity of primary (C) = 700 μFds.

Total leakage inductance referred to primary (l) = 0.25 henry.

Secondary resistance (R_s) = 0.455 ohm.

Primary resistance (R_p) = 800 ohms.

A.C. anode impedance of valve (R_a) = 4,700 ohms.

Step-down ratio of transformer (σ) 24 to 1.

All these values have been referred to the secondary for the purpose of the equivalent circuit.

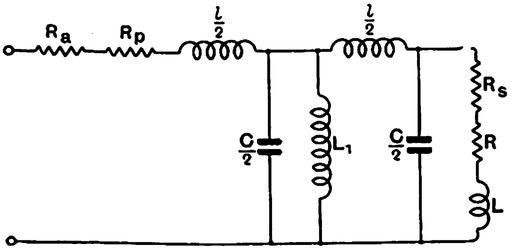


Fig. 9.—*Equivalent circuit of loud speaker, transformer and valve.*

It has been found that this circuit may be considerably modified for various frequencies with sufficient accuracy, thus making calculations much more simple. These circuits are shown in Fig. 10.

The total impedance of the circuit was calculated, and hence the total current assuming 1 volt across the terminals. This corresponds to $\frac{\sigma}{\mu}$ volts on the grid of the last valve, where σ = step-down ratio of the transformer and μ = amplification factor of the valve.

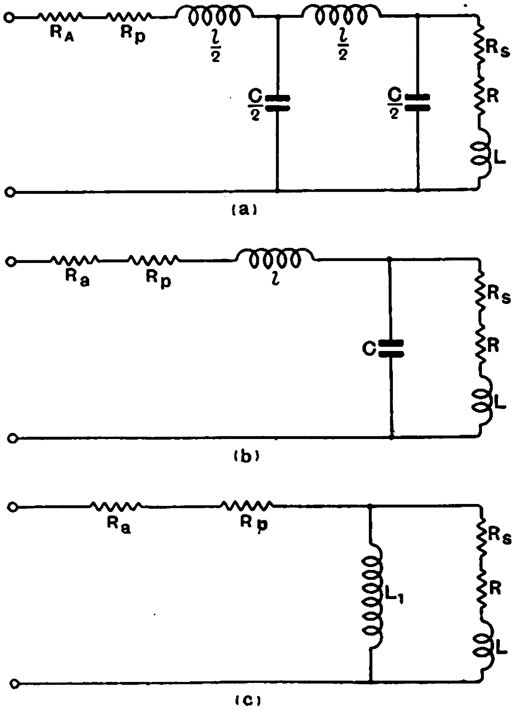


Fig. 10.—*Simplified Equivalent Circuits.*
(*a*) *For frequencies above* 4,000 *cycles.*
(*b*) *For frequencies below* 4,000 *cycles and above* 400 *cycles.*
(*c*) *For frequencies below* 400 *cycles.*

From the total current the current passing through the moving coil was found and hence the output power. The phase angles were calculated as before. Fig. 8, curve B, shows the output power with the transformer in circuit. It will be seen that the overall effect of the transformer and valve is to flatten the characteristic particularly at the lower end.

7. Effect of the Amplifier Characteristic.

If the overall voltage amplification characteristic of the amplifier is known, the overall performance of the loud speaker and amplifier may be found. As the loud speaker had a falling characteristic the amplifier was made to have a rising curve in an effort to compensate for this. The resulting overall characteristic for a uniform input to the amplifier is shown as a dotted curve which approximates to a horizontal line over the useful frequency range.

8. Conclusion.

The results are instructive in that they show two faults in the design of the speaker. First, there is a serious resonance in the order of 40 cycles. This undoubtedly is due to the diaphragm, as when it was tapped and the ear placed close there was a definite very low-frequency note produced. This resonant frequency could be lowered by increasing the effective mass of the diaphragm or reducing the elastic control of the suspension. The latter is by far the more favourable method. To find this resonant point more exactly the resistance was plotted against reactance for clamped and free diaphragm. By joining points of equal frequency on the two curves the motional impedance is found for any frequency. The maximum motional impedance occurs at the resonant frequency. The frequency scale is very open round the loop of the curve, enabling the resonance point to be found with great accuracy.

The other undesirable feature is the falling off of output power at the higher frequencies due to the increased reactance. Less inductance in the moving coil would decrease this effect at the expense of overall efficiency.

It should be noted in passing that the output resistance divided by total resistance will give a figure for the efficiency of the instrument alone. This is about 16 per cent. at 100 cycles, and falls to 6.4 per cent. at 6,000 cycles. This rather high figure is, of course, reduced in practice owing to the losses occurring in the rest of the resistance in circuit.

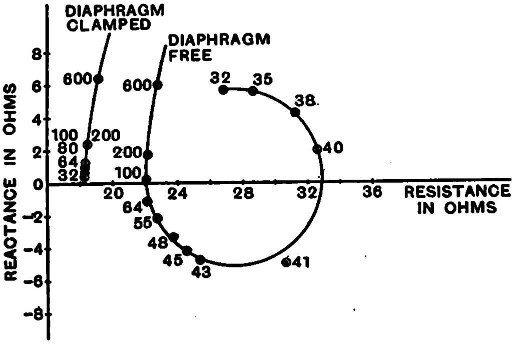


Fig. 11.—*Reactance-resistance Diagram.*

In conclusion, therefore, a much better instrument would result by reducing the elastic control on the diaphragm and using fewer turns on the moving coil.

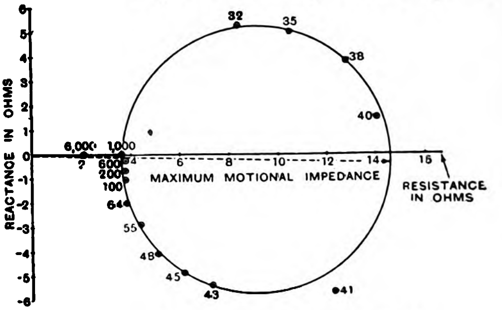


Fig. 12.—*Motional Impedance Circle.*

The authors are indebted to the Northampton Engineering College, London, for the experimental facilities provided and to Mr. A. C. Jolley for his keen interest throughout the work.

APPENDIX.

Equations of Motion for a Moving Coil Loud Speaker.

In deriving the equations of motion for the diaphragm we have a force F acting on the moving coil. Three assumptions are made, as follows :—

1. The actual distributed mass can be considered as a concentrated mass intimately associated with the moving coil.
2. The elastic restraint produces a force proportional to displacement and can be considered as concentrated and fixed to the equivalent mass.
3. The output power can be considered as a frictional force, concentrated and acting on the moving coil, and its magnitude is proportional to the velocity of movement. This seems to be substantiated by previous investigators, and it is of interest to note that some output power is absorbed by the air viscosity and the viscosity of the diaphragm and suspension materials, and that such viscosity produces a force proportional to the velocity of relative displacement. We therefore write

$$F = (MD^2 + KD + K_1)x$$

where M is the equivalent mass and has dimensions $MLT^{-2} \div LT^{-2} = M$

K is the equivalent resistance and has dimensions $MLT^{-2} \div LT^{-1} = MT^{-1}$

K_1 is the equivalent elasticity and has dimensions $MLT^{-2} \div L = MT^{-2}$

x is the displacement in the direction of the force.

The greatest difficulty is to decide the magnitude of the various components. Since the edge of the disc is only semi-free it does not vibrate as a plane disc, but bends in a manner similar to the prong of a tuning fork, and the effective mass will be some fraction of the static mass which will vary with frequency, while at low frequencies the inertia of the air must also be allowed for.

The resistance component is only approximately an equivalent output resistance, as at the higher frequencies especially losses take place in the diaphragm material itself. For losses other than those proportional to the velocity of movement the effect will be to modify the reactance components as well as to increase the losses.

The effective elasticity, though probably given correctly by a static test for the lower frequencies, is not correct at the higher frequencies, when the disc probably vibrates in a complex manner, dividing into various resonating sections at various frequencies (*see E.W. & W.E.* Editorial, Dec., 1927). The elasticity thus varies with frequency, and since the efficiency is so high some allowance must be made for the air elasticity.

To find the force on the moving coil let B be the flux-density, l be the active length of wire in the coil and $I \cos \omega t$ the current flowing.

$$F = lBI \cos \omega t = (MD^2 + KD + K_1)x$$

On solving for the steady state, *i.e.*, neglecting all transient effects,

$$x = \frac{\frac{lB}{M}\left(\frac{K_1}{M} - \omega^2\right) I \cos \omega t + \frac{K}{M} \cdot \frac{lB}{M} \omega I \sin \omega t}{\left(\frac{K_1}{M} - \omega^2\right)^2 + \frac{K^2}{M^2} \omega^2}$$

Let $$\left(\frac{K_1}{M} - \omega^2\right)^2 + \left(\frac{K}{M}\right)^2 \omega^2 = Z^2.$$

The coil movement induces into itself a back E.M.F. given by $e_1 = lB \frac{dx}{dt}$.

If the coil circuit has inductance L and resistance r and letting current flowing in it be $I \cos \omega t$ as above, we have that

$$- \omega LI \sin \omega t + rI \cos \omega t = e - e_1$$

where e is the applied E.M.F.

Now $$e_1 = \frac{(lB)^2}{M^2} \frac{K_1}{Z^2} \omega I \sin \omega t + \frac{(lB)^2}{MZ^2} \omega^3 I \sin \omega t + \frac{(lB)^2}{M^2 Z^2} K \omega^2 I \cos \omega t$$

or $$e_1 = \text{“} A \text{”} + \text{“} B \text{”} + \text{“} C \text{”}$$

Consider K and K_1 non-existent, then $e_1 =$ “ B.” Therefore

$$- \omega LI \sin \omega t + rI \cos \omega t + \frac{(lB)^2}{\omega M} \sin \omega t = e.$$

Hence term “ B ” represents a condenser and has a capacity $C = \frac{M}{(lB)^2}$. This gives dimensionally $\frac{M}{\mu MLT^2} = \frac{1}{\mu LT^2}$, which are the dimensions of a capacity.

The dimensions of K are MT^{-1}, of K_1 are MT^{-2} and of Z^2 are T^{-4}

Now consider the term “ A.”

Dimensionally we have $\frac{\mu MLT^{-2} \,.\, MT^{-2}}{M^2 T^{-4}} = \mu L$, which are the dimensions of an inductance and since the term has a multiplier $\omega I \sin \omega t$ we can consider this term as having a positive reactance given by an inductance of value $l_1 = \frac{(lB)^2}{M^2} \frac{K}{Z^2}$.

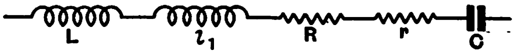
Considering term “ C ” we have dimensionally

$$\frac{\mu MLT^{-2} \,.\, MT^{-3}}{M^2 T^{-4}} = \mu LT^{-1},$$

i.e., the dimensions of a resistance, and this is also shown as the impedance gives an E.M.F. in phase with the current. We can therefore write

$$\left(L + \frac{(lB)^2 K_1}{M^2 Z^2}\right) \omega I \sin \omega t - \left(r + \frac{(lB)^2}{M^2 Z^2} \omega^2\right) I \cos \omega t - \frac{l^2 B^2}{MZ^2} \omega^3 \sin \omega t = e.$$

Hence we can represent the arrangement by the equivalent circuit as shown



L = Loud speaker static inductance.

$l_1 = \frac{(lB)^2}{M^2 Z^2} K_1$ or reflected inductance due to motion.

r = Loud speaker static resistance to A.C.

$R = \frac{(lB)^2}{M^2 Z^2} \omega^2 K$ or reflected resistance due to motion.

$C = \frac{MZ^2}{(lB)^2 \omega^4}$ or reflected capacity due to motion

$$Z^2 = \left(\frac{K_1}{M} - \omega^2\right)^2 + \left(\frac{K}{M}\right) \omega^2.$$

Thus the reflected impedance components vary with frequency especially about the region of $\frac{K_1}{M} = \omega^2$.

Consider three frequency bands :—

1. When ω is small,

$$\frac{K_1}{M} \gg \omega^2 \text{ and also} \gg \frac{K}{M} \omega \qquad \therefore Z = \frac{K_1}{M}$$

$$l_1 = \frac{(lB)^2}{K_1}, \qquad R = \frac{(lB)^2}{K_1^2} K \omega^2,$$

$$C = \left(\frac{K_1}{lB}\right)^2 \cdot \frac{1}{M \omega^4}.$$

Thus at very low frequencies the output resistance is proportional to $\left(\frac{\omega}{K_1}\right)^2$ and the advantage of reducing the elastic control is easily seen. For very low frequencies the reactance due to the condenser will decrease at a rate proportional to ω^3, but this only occurs at very low frequencies.

2. When $\frac{K_1}{M} = \omega^2$, i.e., $Z^2 = \left(\frac{K}{M}\right)^2 \omega^2 = \frac{K^2 K_1}{M^3}$.

Now considering the reactance components, we have

$$\left\{L + \left(\frac{(lB)^2}{MZ^2}\ \frac{K_1}{M} - \frac{(lB)^2\omega^2}{MZ^2}\right)\right\} \omega I \sin \omega t.$$

This reduces to $\omega LI \sin \omega t$ when $\frac{K_1}{M} = \omega^2$. The added reactance is zero and the effective reactance is given by ωL. If ωL is very small the mechanical resonance is at the same frequency as the electrical resonance which was confirmed by tapping the diaphragm.

The resistance at resonance is given by $R = \frac{(lB)^2}{K}$.

3. At high frequencies where

$$\omega^2 \gg \frac{K^2}{M^2} - \frac{2K_1}{M},\ Z = \omega^2$$

$$l_1 = \frac{(lB)^2}{M^2}\ \frac{K_1}{\omega^4}.$$

$$C = \frac{M}{(lB)^2}$$

$$R = \frac{(lB)^2}{M^2} \cdot \frac{K}{\omega^2}.$$

At such frequencies the addition of l_1 is negligible, and the reactance of C is also negligible. This confirms the experimental results, as at high frequencies the motional and static reactance were the same.

The greater the frequency the smaller the output resistance, but it is independent of the elasticity. It is plain that the mass of the diaphragm seriously curtails the output at higher frequencies. Owing to the disc vibrating in various modes at these frequencies, however, other resonances take place, and the effective mass is probably reduced.

The assumption has been made that the driving force is in phase with the coil current and that the induced back E.M.F. is in phase with the coil motion. If the eddy current losses and hysteresis losses are low this should be so, and as the circle diagram gives a very small or inappreciate dip below the resistance axis these assumptions are probably justified.

National Physical Laboratory Annual Visit.

Matters of Wireless Interest.

THE annual inspection of the National Physical Laboratory, Teddington, was held on Tuesday, 26th June, and was, as usual, largely attended by visitors interested in every branch of science. As in former years, all departments of the laboratory were open to visitors, who were afforded an excellent idea of the extent and variety of the work carried out, and of the highly useful function which the establishment serves in industrial science.

While many exhibits of great interest were on view in every department, we are compelled by space to limit ourselves to those of more or less direct wireless interest, especially in the different sections of the electricity department.

Wireless Section.

In the wireless section many items of interest were to be seen.

A short-wave transmitter for wavelength range of 2 to 100 m. was on view, working in conjunction with a Lecher wire system for measurement of the wavelength. This was demonstrated in operation by the location of voltage nodes. A small portable transmitter for use with experimental direction-finding receivers was also shown, as was apparatus for the transmission of standard calibration waves. Wavemeters on view included the oscillator (described by Colebrook), suitable for the generation of C.W. or of modulated oscillations from 5 to 20,000 m., while a wavemeter more especially for the short waves was also shown in operation.

Amongst receivers was one for waves of 5 to 100 m., while a complete D.F. receiver (with its frame aerial electrostatically screened for the elimination of vertical) was shown in operation in conjunction with its supersonic amplifier.

Another interesting exhibit was of apparatus for electric and magnetic screening. This comprised boxes (of commercial production) made of plywood covered with metal, suitable for the housing of receiving apparatus, oscillators, etc., while another group included coupling coils suitable for measuring purposes, electrostatically screened from each other, and boxed for screening from external fields.

In this section also, were exhibited high-grade variable air condensers, using quartz pillars (commercially produced to N.P.L. model and specification) and apparatus for measuring capacity and losses in condensers by a quick and sensitive method.

In another section, there was on view a Cathode ray oscillograph apparatus for the study of wave-forms from amplifiers, oscillators, etc. A linear time-base permits the ready examination of the wave form of the voltage applied to the plates of the tube producing vertical deflection of the fluorescent spot. Arrangements for the measurement of amplification were features of considerable interest. These comprised a high-power amplifier for the fundamental study of amplifier operation under various conditions. Apparatus for receiver measurements generally comprised a large screening chamber for radio and audio-frequency oscillators, the whole chamber being closed by a mercury seal. The output was led through careful screening to another screened room where the receiver was located, and where accurately known values of modulated or unmodulated H.F. voltage could be injected into the receiver under test.

Standards Division.

In the Electrical Standards and Measurements Division, were to be seen many exhibits of the high degree of precision associated with this division.

Amongst these was the standard harmonic wavemeter for the accurate measurement of radio-frequencies from 10 k.c. to 50 megacycles (30,000 m. to 6 m.). A novel exhibit was an inter-ferometer for examination of the modes of vibration of quartz crystal plates, this being shown in operation.

Apparatus for dielectric measurements included a method for the measurement of the permittivity and power factor of dielectrics in the form of thin sheets, and apparatus for the measurement of power factor and permittivity of dielectrics at radio-frequencies, and at known temperatures and conditions of humidity.

Several interesting A.C. bridge methods were also on view. Amongst these was a Schering bridge, shown in operation in conjunction with a screened input oscillator, for the measurement of inductance, capacity and effective resistance at radio-frequencies. A bridge method of measuring the mutual conductances of valves was also on view, while a form of Hay's bridge permitted measurement of the effective inductance and resistance of iron-cored chokes carrying both D.C. and A.C., each component being adjustable to any desired amount.

In this section, also, was apparatus for measuring the amplification and phase relationship in amplifiers at frequencies from 25 to 6,000, while, among magnetic tests, was equipment for measurement of the total power losses at power and at telephonic frequencies in magnetic sheet materials.

One Million Volts.

Although not directly of wireless application, a demonstration of extraordinary interest was shown in the High Voltage Laboratory. Three transformers in cascade, capable of developing up to about 1,000,000 volts were shown in operation, the voltage being gradually built up until it flashed over an insulator of about 6 feet. The transformers are specially designed to facilitate research measurements at extra high voltage, and the display is believed to be the highest voltage so far used in this country. The copious brushing from the conductors during the building up of the voltage was itself spectacular, but the final flash over was a sight unique to those accustomed to more modest voltages.

A Graphical Construction for Resistance Amplifiers.

By *W. A. Barclay, M.A.*

IN a recent issue of this journal Mr. A. L. M. Sowerby deduced a series of equations from which the best values of anode resistance, grid bias, etc., to secure maximum output for a particular amplifying valve might be calculated. [*E.W. & W.E.*, April, 1928, "Calculations for Resistance Amplifiers," by A. L. M. Sowerby, M.Sc.] A simple graphical method of solving these equations will now be described by means of which not only the external resistance R to be used, but also the various other quantities dealt with in Mr. Sowerby's article may be readily obtained. The method depends on the properties of the parabola, but one curve having been set out once for all as described below, the same diagram may be made to serve for any number of valves. The symbols employed and the numeration of the equations are those of the article in question, to which readers are referred.

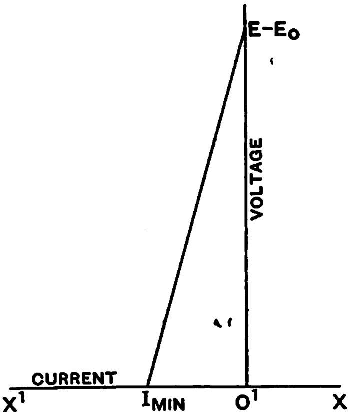


Fig. 1

In the diagram of Fig. 1, let current in milliamps. be measured along $O'X'$ to the left of O' to any convenient scale of representation, while voltages are measured upwards from O' on the vertical line, again to any desired scale. Then, if v be the voltage drop across a resistance R due to the passage of a current i, a measure of R will be afforded by the slope of the line joining v to i on their respective scales. We shall seek on this diagram the points corresponding to the voltage $E - E_0$ and to the current $I_{\text{min.}}$ for our particular valve, and shall refer to the gradient of the resulting slope line as G.

We now prepare another diagram, Fig. 2, whereon the x-axis is graduated linearly in resistances to any convenient unit, while vertically above each resistance graduation a point P is taken such that the slope OP is identical with the slope of the same resistance taken on the diagram of Fig. 1. It is easy to show that the locus of these points is a parabola to which the x-axis is tangential at the origin, and that the ordinates to the curve are proportional to the squares of the corresponding resistances.

If, now, a line of slope G meets this parabola at a point P whose abscissa is $R + R_0$, the ordinate PQ will be $(R + R_0)^2$. But from equation (3) of Mr. Sowerby's article

$$\frac{(R+R_0)^2}{R_0} = \frac{E-E_0}{I_{\text{min.}}} = G = \frac{PQ}{NQ}.$$

so that NQ will represent R_0. Hence ON will measure R, the value of external resistance to be used.

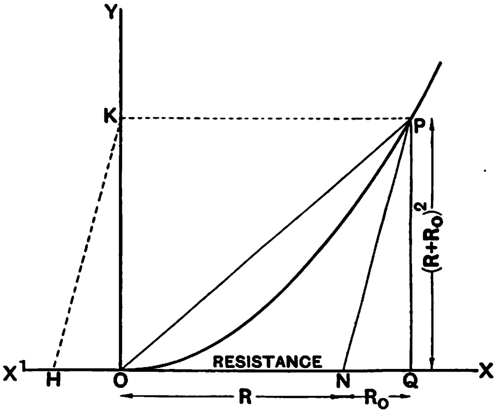


Fig. 2

This property is made use of practically as follows. From O in the reverse direction OX' set off OH equal to R_0 and through H draw a line of slope G to meet OY in K.

Draw KP parallel to OX to meet the curve in P, PN being then drawn of slope G to meet the x-axis in N.

Consider now the diagram of Fig. 3, in which the position of P and the value of $ON = R$ have been obtained by the above construction. Draw NV to meet the curve in V, and join OV to meet PQ in M. Then from Mr. Sowerby's equations (2) and (3) and the properties of the parabola it may be shown (see Appendix I) that

$$PQ : MQ : VN :: E - E_0 : -2\mu E_g : 2V.$$

This leads to the following simple construction to obtain these quantities, as well as I_a and I_aR of Mr. Sowerby's equations (5) and (6).

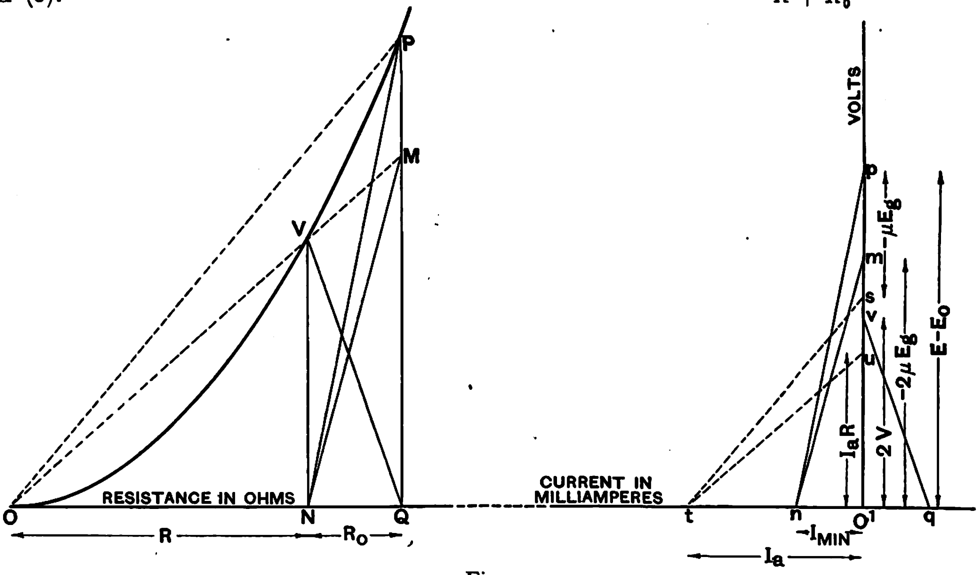


Fig. 3

In Fig. 3 let $O'p$ and $O'n$ represent $E - E_0$ and $I_{\text{min.}}$ as in Fig. 1, and let P be the point on the parabola found as in Fig. 2 so that PN is parallel to pn and $ON = R$.

Join VQ, NP, NM, OM and OP.

Take a point q on the opposite side of O' so that $O'q$ is equal to $O'n$.

Draw qv parallel to QV. Then $O'v$ represents $2V$.

Draw nm parallel to NM. Then $O'm$ represents $-2\mu E_g$. From p measure down $ps = \frac{1}{2}\,O'm$.

Draw st parallel to OP. Then $O't$ represents I_a.

Draw tu parallel to OM. Then $O'u$ represents I_aR. (For proof, see Appendix II.)

Whence, by subtraction,

$$E_a = E - I_aR.$$

APPENDIX I.

Mr. Sowerby's equations (2) and (3) may be re-written :—

$$2V = R\left\{\frac{E - E_0}{R + R_0} - I_{\text{min.}}\right\} \quad .. \quad (2)$$

$$\frac{E - E_0}{R + R_0} = \frac{R + R_0}{R_0} \cdot I_{\text{min.}} \quad .. \quad (3)$$

whence $$2V = \frac{R^2}{R_0} \cdot I_{\text{min.}}$$

Therefore, $$\frac{E - E_0}{2V} = \frac{(R + R_0)^2}{R^2} = \frac{PQ}{VN}$$

Again, since $$I_{\text{min.}} = \frac{E - E_0 + 2\mu E_g}{R + R_0}$$

we have from (2) :

$$\frac{2V}{R} = -\frac{2\mu E_g}{R + R_0}$$

Therefore, $$\frac{-2\mu E_g}{2V} = \frac{R + R_0}{R} = \frac{MQ}{VN}$$

APPENDIX II.

From construction :

$$PQ : MQ : VN :: O'p : O'm : O'v$$

But, $O'p = E - E_0$.

Therefore, $O'm = -2\mu E_g$ and $O'v = 2V$.

Again, $$O's = O'p - \tfrac{1}{2}\,O'm$$
$$= E - E_0 + \mu E_g.$$

But gradient of st = gradient of $OP = R + R_0$.

$$\therefore \quad O't = \frac{E - E_0 + \mu E_g}{R + R_0} = I_a$$

Also, gradient of tu = gradient of $OM = R$.

$$\therefore \quad O'u = I_aR.$$

Fading Measurements in India on the Short-wave Station PCJJ (Holland).

By T. S. Rangachari, M.A.

(Indian Institute of Science, Bangalore, India.)

THE phenomenon of fading is well known to a large number of listeners and in recent years it has been a subject of systematic study by quantitative measurements. These measurements are made in almost all cases on the broadcast band of wavelengths. The idea of Empire Broadcasting extends the importance of fading observations to the short-wave band.

There is a common belief that short-wave broadcasting is subject to no fading. Some while ago a listener in India wrote in the *Wireless World* (Feb. 29th, 1928, p. 235) that no fading was present. But the experience of the author is not the same on PCJJ, the Dutch station, on a wavelength of 30.2 metres, which is regularly listened to, at the Indian Institute of Science, Bangalore. A quick fading was evident and it was decided to make a more quantitative observation than listening could provide. The results of measurement, though they are not extended enough to draw general conclusions, yet were capable of giving some interesting information.

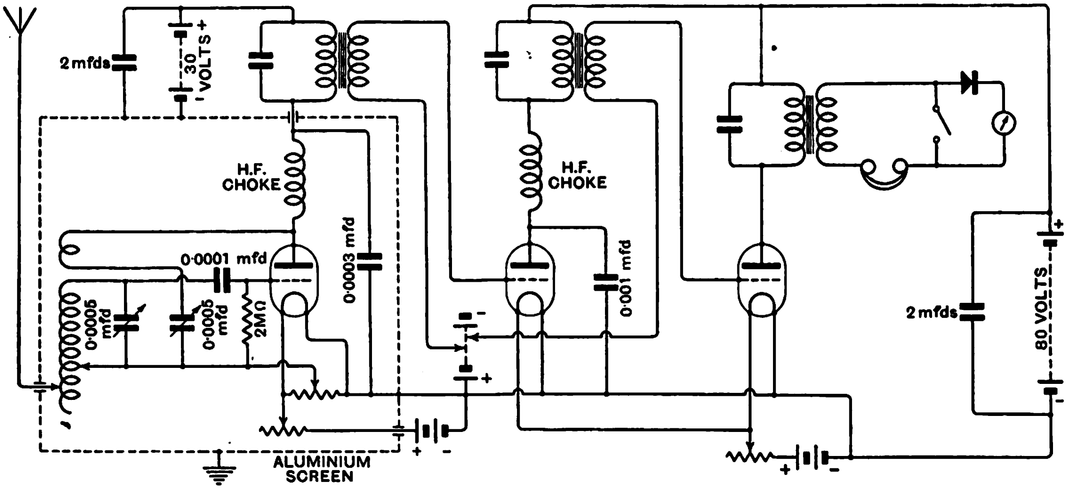


Fig. 1.—*Circuit of the receiver used.*

Method of Measurement.

The usual method of using H.F. amplification and measuring at the detector is difficult in the case of short waves. Therefore recourse was made to measuring on the L.F. side of the receiver. The method adopted is shown in Fig. 1. The H.F. part of the receiver is used in an oscillating condition to get a steady audible beat with the incoming carrier wave and a crystal detector is used to rectify the resulting alternating L.F. current. In series with the crystal a micro-ammeter is connected to read the D.C. current.

The circuit of the receiver is shown in Fig. 1. It consists of a detector with reaction and two L.F. stages. The detector and the coils on the H.F. side are enclosed in an aluminium case which is connected to the negative of low tension and earth. The aerial is a taut vertical wire, 30ft. high, stretched between the work table and the roof inside the laboratory. Any error that may occur due to the swinging of the aerial if erected outside, exposed to the wind, is thus minimised. Since the measurements are made on the L.F. side, it is important to avoid low frequency and "threshold" oscillations by careful wiring and by using a separate battery for the detector. The valves used are P.M.5X.

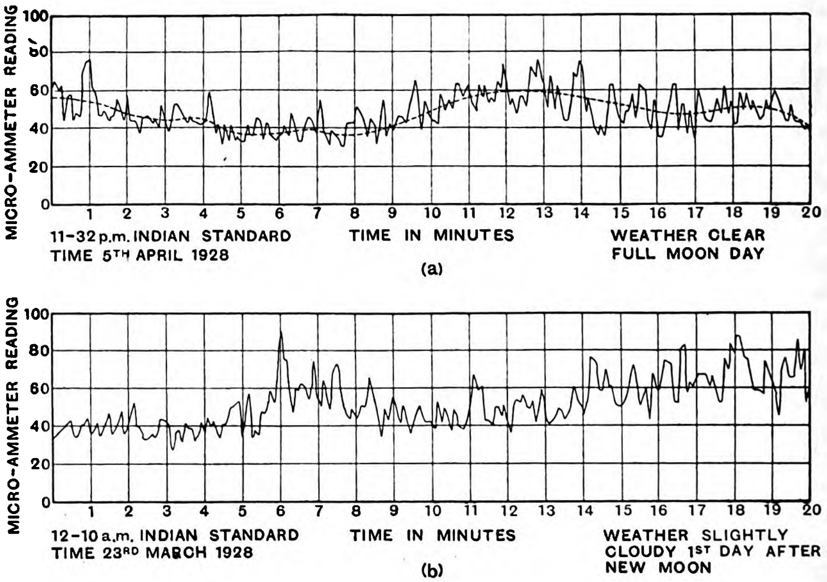


Fig. 2.

This receiver gives comfortable phone strength with absolute silence of background. The crystal, which is fused silicon and silver catswhisker, is found to work satisfactorily for hours together.

Results.

Measurements are taken for periods of 20 minutes at a stretch at intervals of every 5 seconds. In Fig. 2 are given some observed experimental curves. The ordinate represents the deflection of the micro-ammeter, while the abscissa represents time in minutes. These curves are only typical of a number of similar curves obtained during the course of observations for about two months. Though the exact relation of the micro-ammeter reading to fading as perceived by the ear is complicated, one can say that the readings do correspond to the fluctuating effect in the ear which one recognises as fading. It is seen from the results that the intensity of the signal is subject to violent fluctuations of very short period of the order of a few seconds. Also the mean value of this fluctuating signal strength is not constant but varies as shown by the dotted curve in Fig. 2(a). This variation is slow, of the order of 10 minutes. The observations so far made do not indicate any definite period, but the presence of this variation of a longer duration is evident. Thus two kinds of fading effects appear to be present, a quick fading superimposed on one of a longer duration. Further, it is also observed that at no time is the fading so severe as to make the station go out of hearing. The phases of the moon appear to have no effect on the nature of fading.

Some New Applications of Short Radio Waves.

By James Taylor, D.Sc., Ph.D., A.Inst.P., and Wilfrid Taylor, Ph.D., M.Sc.

Introduction.

IT is a curious and striking fact that the scientific toy of to-day is the commercial product of to-morrow. Nowhere has this been so well illustrated as in the development of short electrical waves which, largely neglected by the professional, were investigated by the amateur, but when their scope and usefulness were demonstrated, were applied to such diverse uses as transmission of signals, and high-frequency furnaces for the making of fine ingots. Recently, an entirely new and remarkable property of these waves has been discovered, namely, their property of causing bright luminous electrical discharges in highly rarefied gases. The new field thus opened out offers great interest for the scientist, and merits careful consideration from short-wave wireless enthusiasts.

The Electric Discharge in Gases.

It has always been assumed as a result of extensive experience that gases at very low pressures (say, less than 1/1,000th of a millimetre of mercury, and below the degree of vacuum of a soft X-ray bulb) do not permit of the passage of an electric discharge except at very high voltages. All hard electronic devices, including thermionic valves, are based upon this fundamental property. But within the last few years our ideas upon this matter have been radically altered, and it has been found possible by applying alternating voltages of radio frequency (short waves) to produce luminous discharges at extremely low pressures, and to maintain them with relatively small voltages.

The first experiments along these lines were made by Gutton.[1] At a later date, Kirchner[2] in Germany set himself the task of investigating the potentials required to maintain glow discharges in different gases at various pressures and at radio frequencies. The voltage alternations were produced by commercial transmission valves (Telefunken RS 55), and the oscillations sent out from the transmitter were picked up by another circuit coupled inductively with it by means of Lecher wires, and containing the discharge tube. Frequencies down to 3.5×10^7 were obtained, and luminous discharges appeared in the tube. For the first time, therefore, the possibility of creating the beautiful and interesting phenomena of electrical discharge through gases had been placed in the hands of an amateur owning a few Geissler tubes (which may be purchased very cheaply) without any more elaborate means than his short wave set, and eliminating the very costly induction coil or other elaborate device for producing high voltages.

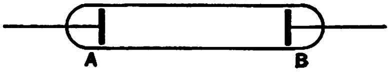


Fig. 1.

Let us consider two metal electrodes *A* and *B* (Fig. 1), mounted in a vessel which is first evacuated and then filled with a known gas at a definite (low) pressure. If now a gradually increasing voltage is put across the electrodes, then at a definite potential, called the sparking potential, a glow or visible discharge begins; an example of this form of discharge is afforded by the well-known neon lamp, now so extensively used for advertising and other purposes. We know, of course, that the discharge is caused by the motion of the electrons in the field between *A* and *B*. When the electrons can acquire a certain minimum velocity and collide with a gas atom, the latter originally neutral atom is dissociated (ionised) into one electron and one positive ion, and by repetition of this process large numbers of electrons and ions are produced. The ions in turn produce more electrons when they strike the cathode, and thus if the potential is sufficiently high, a discharge is maintained. With regard to the luminosity, it is now well known that according to the modern physical picture, the atom consists of a positively charged nucleus surrounded by rotating electrons like a miniature solar system. A certain number of orbits are permissible for each electron, and when the latter jumps from one outer orbit to another inner orbit, light is emitted. Hence light is produced when, as a result of a collision with an electron, electrons are made to change orbits.

---

[1] Gutton, Mitra, and Ylostalo, *Comptes Rend.* 176, 1871, 1923; also Gutton, *C.R.*, 178, 467, 1924.

[2] Kirchner. *Ann der Physik*, 77, 287, 1925.

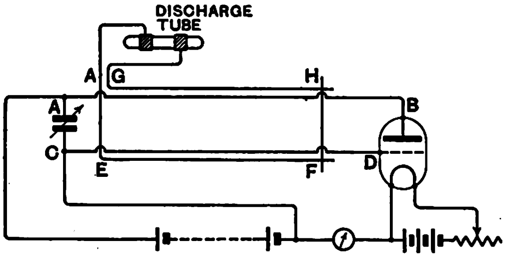


Fig. 2.

Kirchner found that when the frequency of the alternations across the electrodes attained radio values the potential required to maintain the discharge began to fall, and attained, in some cases, extremely low values. Thus, in the case of neon at pressures between 1.5 and 2.0 mms., the discharge could be maintained at a potential of 15 volts with a frequency of 3.5×10^7 cycles. These high-frequency undamped oscillations were capable of maintaining the discharges at low potentials and pressures, in certain circumstances, even at pressures less than those in cold cathode X-ray bulbs. This is a surprising result, for it is well known that for ordinary low-frequency voltages the potentials required to maintain a discharge become progressively higher with decrease of pressure; thus at X-ray stages they are of the order of many kilovolts.

Professor R. W. Wood and A. L. Loomis[3] in America have applied the new discharges to excite spectra in various gases. They used tubes provided with external tinfoil electrodes, and obtained brilliant discharges in hydrogen (blue) and make the remark that, judging from the appearance, they would have estimated the gas pressure at 1 mm., yet with internal electrodes no discharge could be obtained from an induction coil giving a 2-inch spark in air. Effects of fluorescence and red glows on the glass walls were also obtained.

More recently, the present writers have studied the electrical conditions of these discharges.[4] The oscillating circuit was of the type introduced into this work by Gill & Donaldson[5], and is shown in Fig. 2. An Osram L.S.5 valve, the plate and grid being connected as shown to two parallel copper wires about 1½ yards in length and about 3 inches apart. It is not possible to place the discharge tube in this circuit directly on account of its disturbing effect, hence the oscillations radiated from the "transmitter" are picked up by the tuned system *EFGH* coupled to the first by the familiar Lécher wire method. Across the ends *AC* of the first pair of wires a condenser is shunted, the magnitude of which is not of very great importance providing it is of the order of a milli-microfarad. The point *A* is connected to the positive of a high-tension battery of about 400 volts, and the grid wire *C* to the negative. It has since been found possible to use 220-volt direct supply mains in place of the high-tension battery, a resistance being inserted for safety. Experiments were carried out with tubes containing internal electrodes (see Fig. 1), but it was found on the whole to be much easier to maintain the discharge with external electrodes. Consequently, such tubes as shown in Fig. 3 were frequently employed.

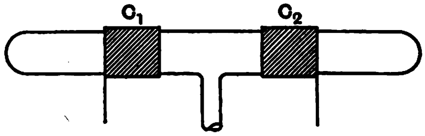


Fig. 3.

The electrodes took the form of annular rings of copper foil wrapped round the outside of the glass tube. The discharges obtained in this way are usually referred to as "electrodeless discharges." If we require a rough gauge of the pressure in such a tube, we may employ an internal electrode tube of the form shown in Fig. 1, and connect the electrodes to the terminals of an induction coil, adjusting the spark gap until a discharge just fails to pass in the tube. This alternative spark-gap distance then gives a rough measure of the hardness of the vacuum, although for precise measurements, of course, a proper gauge must be used.

---

[3] Wood and Loomis, *Nature*, 120, 510, 1927.

[4] *Proc. Cambridge Phil. Soc.*, 24, 259, 1928.

[5] Gill and Donaldson, *Phil. Mag.*, 2, 129, 1926.

General Form of the Discharges.

If we take a typical case of the tube of Fig. 3, and pump it down from atmospheric pressure, then the following phenomena are observed. Air, which is a mixture of nitrogen and oxygen, does not begin to conduct in these circumstances until pressures of 1 mm. or so are obtained. At 0.1 mm. the discharge was of a pink colour (band spectrum of nitrogen), and often took the curious form of a sharply defined egg of bright glow bathed in a faint pink luminosity. The walls of the tube meanwhile glow with an apple-green fluorescence, and the whole appearance, when observed in a dark room, is a most beautiful spectacle. If the pressure is still further decreased, the length of the discharge increases in the tube, and at the same time the luminosity increases, until at a certain stage the colour changes to a dirty blue, dull at first but brightening up later, when it exhibits the characteristic colour of a positive column in mercury, and, in fact, the blue colour marks the stage at which the air has been so far pumped out that the discharge passes in the mercury vapour which diffuses in from the pump. The mercury vapour may be frozen out by immersing the tube in liquid air; nevertheless, faint luminosity still persists. Exact measurements have shown us that even below pressures of 0.00005 mms., these faint glows may be obtained.

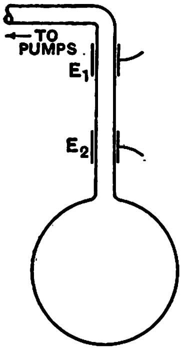


Fig. 4.

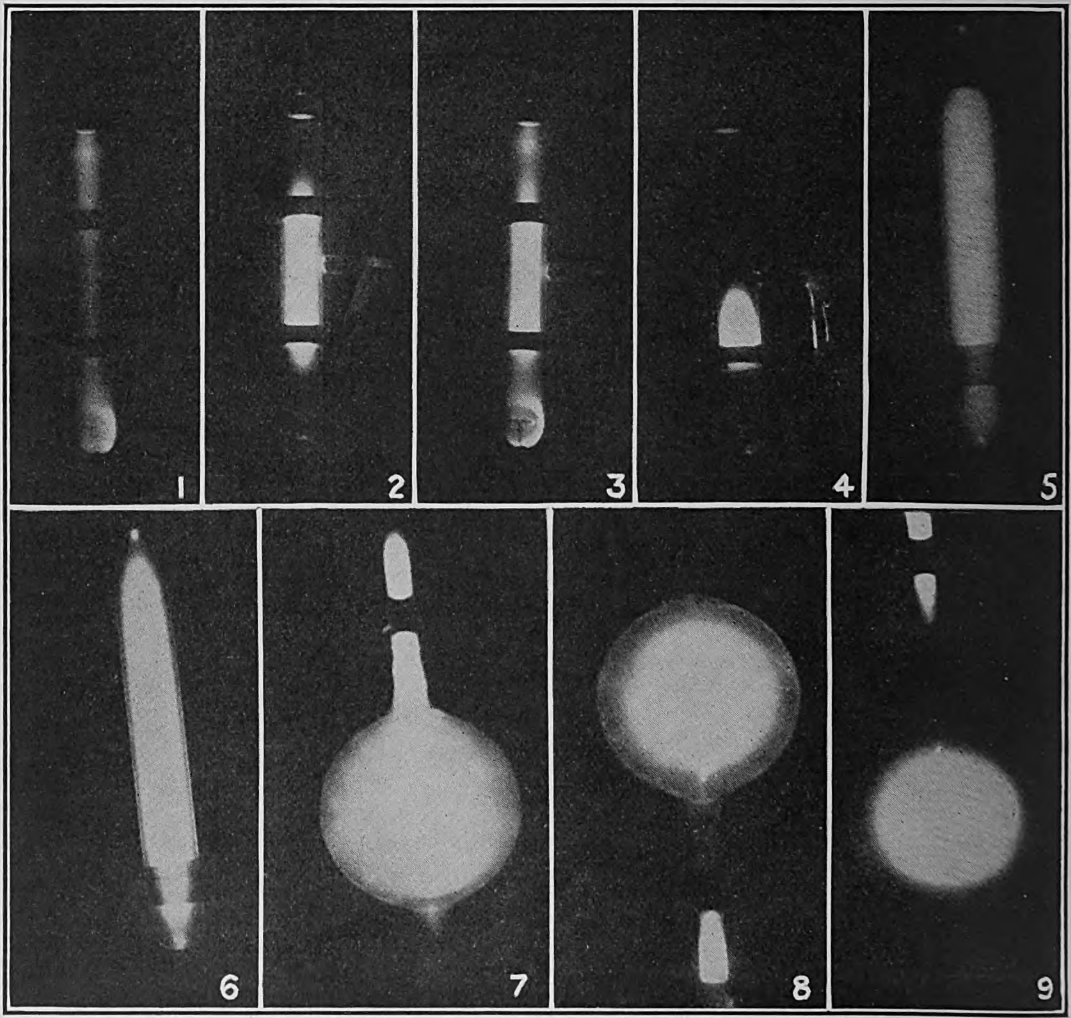
Problems of the High-frequency Discharges.

We may perhaps at this stage indicate briefly the nature of the problems which confront experimenters studying the effect of high-frequency waves in vacuum tubes. Four questions arise naturally: (1) What are the carriers of the discharge? (2) Why are the discharges so strongly luminous? (3) What phenomena take place on the walls of the tube? and (4) Why are the discharges so readily obtained at low pressures? It is easiest to take these questions in the reverse order, and to consider first why it is that similar luminosity cannot be obtained by direct potentials, *e.g.*, by an induction coil. The reasons are to be found in the following facts: (1) The scarcity of collisions between gas atoms or molecules and electrons which prevents accumulation of ionisation by collision. (2) Large quantities of electricity are lost to the electrodes. (3) The positive and negative charges are separated by the field and form "space charges." Now, in the high-frequency discharge, we can overcome all these difficulties. Considering again the tube of Fig. 1, in which the high-frequency voltage is applied between A and B, there is little difficulty in imagining what takes place in the gas. There are always some free ions and electrons in any gas, and these oscillate in the alternating electric field. If the distance travelled by the electron in one-half cycle of the wave is insufficient to take it to one of the electrodes, then there will be very little loss of charge. Most of the electrons remain in the gas and are available to build up more ionisation by collision. Also, since the frequency is so high, there will be no permanent separation of the charges, and as many electrons will vibrate one way as another. Thus there is no effective space charge to destroy the field, and instead we have a cloud of both types of charge. This gives the necessary condition for recombination and the emission of luminosity. It is easy to see also that by using external electrodes even the small loss of charge to the electrodes may be avoided, and the discharge maintained with greater ease.

Discharges in Narrow Tubes.

We pass on to describe more of the effects observed in the tube of Fig. 3, when the discharge was passing in mercury vapour at a pressure of 0.001 mm. Several different types of glows were obtained; in some the luminosity was confined between the electrodes, but in others this space was quite dark and the glows appeared on both sides of it. Sometimes the whole tube was lit up from end to end. All these effects depended upon the distance apart of the electrodes. A strange fact was that even if one electrode was completely taken off the tube, a glow still remained.

If the tube was stroked by the hand (or earthed conductor) on the outside, the glow could be induced to follow the motion of the hand in a most remarkable fashion, and on favourable occasions it was possible to lead the glow round two right-angled bends in the tube and on removing the hand, to leave the whole path still glowing. At other times the glow could be extinguished by pointing the finger at it and touching the outside of the tube.



Photographs of discharges obtained by the methods described.

The discharges pass more readily in wide than in narrow tubes, and there is always a dark space between the glow and the wall. Such dark sheaths are doubtless to be explained by a theory of Langmuir given for similar ones met with in ordinary positive columns. The theory deals with very important considerations of space charge, and has, of course, vital application to thermionic valves. According to this theory, any surface immersed in a cloud of negative and positive charges will tend to charge up negatively in consequence of the swifter motion of the electrons. The surface then repels all but the fastest moving electrons, and creates a sheath in which there is a strong concentration of positive ion space charge. Owing to the lack of electrons for recombination, this sheath will be relatively dark and will moreover serve as a perfect reflector for most of the electrons striking it. Photographs were taken of discharges in a tube of the form shown in Fig. 1, but external electrodes as in Fig. 3 were added, thus the tube was a composite one, including the two forms, Figs. 1 and 3. The filling gas was pure helium at the pressure of about 1/50th mm. Plate 1 shows the discharge obtained on connecting the inside electrodes (*A* and *B*) to the terminals of an induction coil working at over 1,000 volts. Plate 2 shows the high-frequency electrodeless discharge produced when the external ring electrodes (C_1 and C_2) were connected to the oscillating set (Fig. 2). Plate 3 gives the combined effects of the induction coil and the high-frequency voltage. It is at once seen that the electrodeless discharge is much more intense than that given by a direct voltage of 1,000, and it is very remarkable to find that the superposition of a steady voltage of this magnitude across an electrodeless discharge is relatively without influence. The photographs give but a poor idea of the beauty of the actual discharges and their fascinating colour effects. The dark sheaths at the glass walls are well developed, as can be seen very clearly.

Plate 4 shows the same type of discharge after the helium became contaminated with traces of air. The luminosity was confined to a cone of light at one of the electrodes.

Plate 5 is a photograph with a tube of the form shown in Fig. 3 (no internal electrodes). The pressure was very low (residual gas after pumping out thoroughly and maintaining the vacuum by means of charcoal immersed in liquid air) certainly less than one-thousandth of a millimetre, the gas being probably hydrogen. In order that some of the phenomena we have described should be visible within the circular external electrodes, the latter were made of fine wire gauze. The gas pressure was so low that ordinary discharges could only have been produced at many thousands of volts. The electrodeless discharge, however, started without difficulty and, as the photograph shows, was extremely intense. The dark sheaths at the walls, and the constrictions within the annular electrodes are beautifully exhibited. Plate 5 shows a similar discharge in the same tube, with the striking condition that one electrode of the high-frequency voltage feed has been entirely removed from the tube. It may be of interest to mention that the photographs were taken on ordinary Ilford Special Rapid Plates with a large portrait lens, and exposures of only about two seconds.

Discharges in Bulbs.

Still more interesting effects were found to occur when a large glass bulb was used for the experiments. The bulb was about 20 cms. in diameter, and fitted with a side tube upon which the external electrodes were mounted as shown in Fig. 4. The filling gas was mercury vapour as before.

The first type of discharge has been termed "Type A," the side tube was filled with the same luminosity as described previously, and this extended right down into the bulb in the form of a luminous streamer. The streamer was surrounded by a diffuse and fainter glow which completely filled the bulb. There was no dark space round the walls. [Plate 7. Unfortunately the streamer cannot be obtained in a photograph.]

This appearance was, perhaps, what might have been expected, but on reducing the power in the oscillating circuit, the whole discharge underwent a sudden change and collapsed into a perfectly different form, which we shall call Type B. The luminosity in the side tube disappeared entirely, and with it the bright streamer. The glow in the bulb took the form of a perfect sphere floating in the centre of the bulb, but separated from it everywhere by a dark space of uniform thickness. [Plate 8. Plate 9 shows Type B in nitrogen at low pressure.] This glow was largely unaffected by external agencies; for example, moving an earthed conductor about the outside of the bulb produced no effect, and a magnetic field which bent the streamer of Type A into a semi-circular arc merely caused the sphere to brighten slightly.

It is striking that these discharges lend themselves very well to photography. With an F/4.5 portrait lens, the photographs reproduced in this article were obtained after an exposure of 3 seconds, even though it was necessary to darken the room to exhibit the discharges properly to the naked eye. The radiations from the high-frequency discharge are, therefore, of a high actinic power.

From many points of view we may regard the glowing sphere as an enclosure of positive and of negative ions at a uniform high temperature. It might seem strange at first sight to talk of temperature in connection with electric charges, but it is a perfectly justifiable usage. We know that temperature merely measures the kinetic energy with which atoms and molecules are actuated in bulk whilst suffering mutual collisions. In the same way ions may move and collide. We have in fact by the high-frequency electric field a method by which their speeds and therefore their energies may be very greatly increased. Langmuir has estimated the temperature of the electrons in a positive column of mercury at the enormous figure of 600,000 degrees Centigrade, and considerably less than this for the positive ions. Thus, when a gas molecule is shot into the glow, there is a chance that it will be struck by a body at a " temperature" of thousands of degrees, and the result will be that the molecule will emerge from the encounter with properties appropriate to the high temperature, *e.g.*, different chemical activity, or even in the form of fragments. The molecule of hydrogen, for example, might be expected to be dissociated into two atoms and the new discharge may thus be a means of producing that striking substance, atomic hydrogen. Finally, it may be remarked that the sphere discharge bears a most striking resemblance to the solar corona seen during a total eclipse, and there is reason to suppose that the conditions may in some ways be indeed very similar. It can well be that a near approach to celestial phenomena may be reached in the laboratory.

Of more pertinent application of the new phenomena to radio, there seem to be several possibilities. Thus, the theory and practice of valve functioning at very high frequency is not entirely known, and it is possible that discharge effects of the type we have described may play an important part in certain valves if the voltage fluctuations are sufficient. It is also tempting to think that new light may be thrown upon the nature of the Heaviside layer now that demonstration of the absorption of Hertzian waves in highly rarefied gases has been made. It is interesting to speculate that high-frequency waves of celestial origin may produce sufficient ionisation in the upper layers of the earth's atmosphere.

Applications.

The application of short-wave discharges has already led to results of interest and importance.

It is an extremely powerful tool for studying certain chemical actions that are of vital importance in industry, and it supplies possibilities of working under the extreme conditions of refinement and purity which are the ideal of scientific investigation.

Further, it has yielded information on the obscure problem of what part the glass walls play in " softening " and " hardening " of valves, electric lamps and the like. " Softening " or " hardening " of an electronic device means change of the gas content and this is frequently fatal to repeatability and constancy of performance. It may be of interest to state that it is found that glass must be regarded as a sort of viscous, stiff liquid containing particles of matter charged some with positive, some with negative electricity. These charged particles sometimes break down under electrical influence and give off gas, on the other hand they can, under favourable conditions, seize gas molecules that come up to the walls and hold or fix them.

The Harmful Effects of Inter-electrode Capacity.

By Manfred von Ardenne and Wolfgang Stoff.

IN all amplifiers, whether for high or low frequencies, the capacities between the electrodes of the valves stand in the way of making the fullest use of the amplifying action of the valves. On this account the amplification per stage cannot be increased to the theoretical maximum, but only as far as a certain limit. This limit is fixed by the magnitudes of the stray capacities themselves, but in addition the feed-back effects caused by these capacities between the electrodes must be taken into account. In amplifiers with tuned couplings the reaction between the various circuits caused by the valve capacities nearly always has self-oscillation as its consequence; the capacities themselves, so long as they do not give rise to reaction, can in such a case hardly be termed harmful, for their sole effect would then be an alteration in the tuning of the circuits connected between successive stages. In contrast to this stand amplifiers with aperiodic couplings, in which the shunting effect of the capacities results in a decrease of the amplification per stage with increasing frequency, so that in low-frequency amplifiers there arises an unwelcome variation with frequency, while at radio-frequencies the amplification attained per stage is very small.

The Capacities in a Single Stage.

In order to give a numerical idea of the magnitudes of the stray capacities it may be stated that in the modern high-amplification valves the capacities between the individual electrodes amount to about 1 to 4 $\mu\mu$F., and do not vary greatly in magnitude. To these electrode capacities must be added the parallel capacities of the leads and the parts of the circuit connected to them. In a reasonably carefully constructed instrument the additional capacities so caused will have a value of about 2 to 6 $\mu\mu$F. The measurement of these small capacities is not altogether easy, and requires specially accurate measuring equipment. Moreover, the individual capacities cannot be directly measured on account of the arrangement of the electrodes, but must in all cases be found from the sum of the partial capacities with the help of several measurements and a simple calculation.

For the discussion of the stray capacities and their effects one stage of an amplifier will be isolated and discussed in detail. In Fig. 1, in which this amplifying stage is shown, the three capacities within the valve are indicated by dotted lines. All circuit elements of the grid circuit are included in the impedance $\mathbf{Z}_g$, and those of the anode circuit in $\mathbf{Z}_a$. It hardly needs to be specially mentioned that $\mathbf{Z}_g$ and $\mathbf{Z}_a$ represent complex operators, and include not only the couplings but also the capacities due to the *preceding* and *following* stages. The network of Fig. 2 corresponds to the amplifying stage of Fig. 1, and may be substituted for it. The valve is here replaced in the usual way by an A.C. generator with the E.M.F. $\mu\mathbf{E}_g$ and an internal resistance R_i. From this network there follows at once the well-known equation:

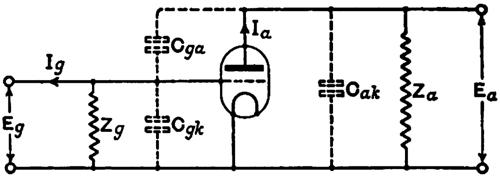


Fig. 1.

$$\mu\mathbf{E}_g = \mathbf{I}_a . R_i + \mathbf{I}_a\mathbf{Z}_A \quad .. \quad (1)$$

Taking as positive the direction of $\mathbf{E}_a$ shown by the arrow in Fig. 2, there follows also:

$$\mathbf{E}_a = -\mathbf{I}_a\mathbf{Z}_a{}^* \quad .. \quad .. \quad (2)$$

The diagram of Fig. 3 is drawn on the basis of these equations. In this diagram there is shown not only the magnitude of the various voltages, but also their phase-angles ϕ or $180 - \phi$ and ψ relative to the anode current $\mathbf{I}_a$. There has been selected the special case in which the impedance $\mathbf{Z}_A$ in the anode circuit consists of a pure resistance shunted by a capacity. . It can be seen from the diagram that the voltage $\mathbf{E}_a$, which from Equation (2) is opposite in direction to the voltage-drop $\mathbf{I}_a\mathbf{Z}_A$, and the voltage $\mu\mathbf{E}_g$, or $\mathbf{E}_g$ itself, are *not* in exactly opposite sense. For further discussion, therefore, $\mathbf{E}_a$ is resolved into two components, of which one, $E_a.\cos(\phi - \psi)$, is exactly opposed to $\mathbf{E}_g$ while the other, $j.E_a \sin(\phi - \psi)$, is at right-angles to $\mathbf{E}_g$.

---

* In this article the symbolic notation is adopted; bold-faced letters represent complex quantities or vectors.

Feed-back Effects across the Grid-anode Capacity.

As Fig. 2 shows, the three valve capacities are so arranged that the capacities C_{gk} and C_{ak} are directly in parallel with the grid and anode circuits respectively. The third capacity C_{ga}, on the other hand, effects a coupling between these two circuits. In consequence of this the alternating voltage $\mathbf{E}_a$ on the anode can reach the grid through the capacity C_{ga}, so producing reaction from the anode circuit to the grid circuit. As the result of this reaction part of the alternating current in the anode circuit flows to the grid, and its effect on the grid circuit is as though there had been connected in parallel with that circuit an additional impedance. The direction of the current flowing to the grid can be seen from the vector diagram of Fig. 4; this part of the anode current corresponds to a grid current of the value:

$$\mathbf{I}_g \text{ react.} = j\omega C_{ga}(-\mathbf{E}_a) = -j\omega C_{ga}.E_a.\cos(\phi - \psi) - j\omega C_{ga}.jE_a \sin(\phi - \psi) \quad .. \quad (3)$$

As the foregoing considerations show, this formula only includes the reaction from the anode circuit. Only the voltage $\mathbf{E}_a$ on the anode resistance reacts back into the grid circuit; in setting up the formula for the total current flowing in the grid circuit it would be necessary to consider the voltage difference $-(\mathbf{E}_a - \mathbf{E}_g)$. As will be shown below, and as can easily be seen from Formula 5, this means no more than that in addition to the impedance due to the feed-back effect the capacity C_{ga} itself is to be regarded as permanently connected in parallel with the grid circuit.

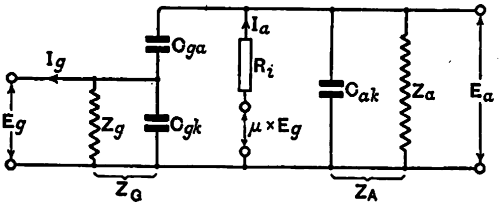


Fig. 2.

On the assumption that C_{ga} is a pure capacity, without losses, the current $\mathbf{I}_g$ react. must be at right-angles to the voltage $\mathbf{E}_g$ (see Fig. 4). The admittance of the corresponding additional impedance just mentioned in the grid-circuit has the value:

$$\frac{1}{\mathbf{Z}_g \text{react}} = \frac{\mathbf{I}_{g1}}{\mathbf{E}_g} + \frac{\mathbf{I}_{g2}}{\mathbf{E}_g} = -j\omega C_{ga}.\frac{E_a}{E_g}.\cos(\phi - \psi) + \omega C_{ga}\frac{E_a}{E_g}\sin(\phi - \psi) \quad .. \quad (4)$$

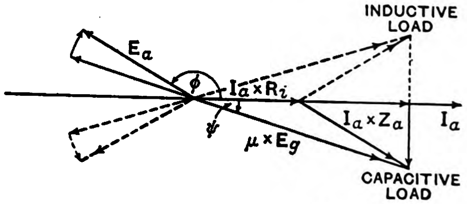


Fig. 3.

As the diagram of Fig. 4 also shows, this part of the current can be resolved into two components, one of which, $\mathbf{I}_{g1}$, is at right-angles to the voltage $\mathbf{E}_g$, while the other component falls along $\mathbf{E}_g$. The additional impedance parallel to the grid circuit can be resolved in a corresponding way into a capacity with a pure resistance in parallel with it; it may therefore be regarded as a condenser with losses. The sign of this resistance depends upon the sense of the voltage-drop $\mathbf{I}_a\mathbf{Z}_A$, and therefore upon the sign of the loading in the anode circuit. In the diagram (Fig. 3) a capacitative loading of the anode circuit is assumed. If this were inductive the diagram would have to be raised above the axis; in this case the voltages shown dotted in the figure would arise. As before, the additional impedance in the grid circuit would be made up of a capacity and a resistance in parallel. This resistance, however (corresponding to the component of current $\mathbf{I}_{g2}'$, in contrast to the case already discussed), is negative; if this negative resistance is numerically greater than the positive resistances of the grid circuit, self-oscillation will occur. In conclusion, it should be mentioned that in addition to the extra impedance caused by feed-back from the anode circuit, the grid-anode capacity itself is *always* present as a load on the grid circuit, even when the anode circuit is short-circuited ($\mathbf{Z}_a = 0$); but as there is in this case no alternating voltage $\mathbf{E}_a$ on the anode, there can be no reaction into the grid circuit. From the equations deduced above and the circuit diagram of Fig. 2 there follows for the total admittance of the grid circuit this equation:

$$\begin{aligned}\frac{1}{\mathbf{Z}_G} &= \frac{1}{\mathbf{Z}_g} + j\omega C_{gk} + j\omega C_{ga}\left(1 - \frac{\mathbf{E}_a}{\mathbf{E}_g}\right)\\ &= \frac{1}{\mathbf{Z}_g} + j\omega C_{gk} + j\omega C_{ga} - j\omega C_{ga}\cdot\frac{E_a}{E_g}\cos(\phi - \psi)\\ &\qquad + \omega C_{ga}\frac{E_a}{E_g}\sin(\phi - \psi) \quad .. \quad (5)\end{aligned}$$

From this equation, and from what has been said above, there follows the well-known and important fact that the magnitude of the feed-back depends on the ratio $\frac{E_a}{E_g}$, or, in other words, upon the voltage amplification of the stage.

In cases where the assumption made above, that the insulation-resistances parallel to the valve capacities can be neglected, does not apply, the admittance $\frac{1}{R_{ga}} + j\omega C_{ga}$ must be substituted for the admittance $j\omega C_{ga}$ in the formula. Formula (5) then takes the form:

$$\begin{aligned}\frac{1}{\mathbf{Z}_G} &= \frac{1}{\mathbf{Z}_g} + j\omega C_{gk} + \Big(j\omega C_{ga}\\ &\quad + \frac{1}{R_{ga}}\Big)\left(1 - \frac{E_a}{E_g}\cos(\phi - \psi) - j\frac{E_a}{E_g}\sin(\phi - \psi)\right.\\ &= \frac{1}{\mathbf{Z}_g} + j\omega C_{gk} + j\omega C_{ga} - j\omega C_{ga}\frac{E_a}{E_g}\cos(\phi - \psi)\\ &\qquad - \frac{1}{R_{ga}}\cdot j\cdot\frac{E_a}{E_g}\sin(\phi - \psi) + \frac{1}{R_{ga}}\\ &\qquad\qquad - \frac{1}{R_{ga}}\cdot\frac{E_a}{E_g}\cos(\phi - \psi)\\ &\qquad\qquad + \omega C_{ga}\frac{E_a}{E_g}\sin(\phi - \psi) \quad .. \quad (5a)\end{aligned}$$

Since for capacitative loading of the anode circuit the angle $(\phi - \psi)$ lies between 90 deg. and 180 deg., for this case the ohmic resistance appearing in the grid circuit will be considerably increased on account of feed-back over the insulation resistance Z_{ga}; the capacity appearing in the grid circuit will, however, be slightly decreased. If the load in the anode circuit is inductive $(\phi - \psi)$ lies between 180 deg. and 270 deg., and the sine becomes negative, so that there results on the one hand a reduction of damping, and on the other an increase in the added capacity of the grid-circuit.*

Besides the reaction from the anode circuit already discussed, there exists a similar transference of energy from the grid circuit to the anode, which also takes place through the grid-anode capacity. This effect will not be gone into more deeply here, for it behaves in a manner exactly opposite to the feed-back from anode to grid, and therefore decreases as the voltage amplification of the stage increases. Even when the voltage amplification is comparatively low the effective capacity introduced into the anode circuit by transference of energy from the grid can be neglected in comparison with the capacity C_{ak} between anode and cathode.

Effect of the Feed-back from the Anode in Different Types of Amplifier.

In considering the effect of the feed-back from the anode in the various types of amplifier we shall have, according to the considerations just advanced, three different cases to distinguish, each case corresponding to a different type of load in the anode circuit. If the total impedance $\mathbf{Z}_A$ in the anode circuit is purely resistive, the additional impedance in the grid-circuit is capacitative only, for in this case no additional resistance enters. In practice, however, a purely resistive load is very difficult of realisation. It is true that in tuned amplifiers the anode impedance may be regarded as purely resistive when the circuits are exactly in resonance, but this ideal case is no longer realised when these circuits are detuned to even the slightest

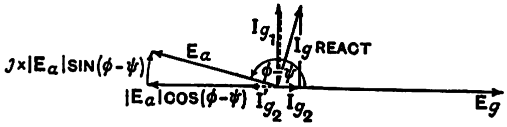


Fig. 4.

---

* *See* L. Hartshorn, "The Input Impedances of Valves at Low Frequencies," *Proc. Phys. Soc.*, Vol. 39, Part 2, 15th Feb., 1927.

extent. The direction of the detuning decides which of the two remaining cases applies. In amplifiers in which the coupling is by resistance only the ideal case only occurs at very low frequencies. Here, however, the harmful capacities no longer play any part. At high frequencies we at once have the case of a pure resistance shunted by a capacity, which will now be considered.

If the anode circuit consists of a pure resistance shunted by a capacity, or, more generally, if the anode circuit can be regarded as capacitative, then, in addition to the capacity already mentioned, there is introduced into the grid circuit by the feed-back from the anode a positive real component; that is to say, a positive ohmic resistance. This case is of importance for the calculation of the effects of frequency in resistance-coupled low-frequency amplifiers.* In this calculation it must be remembered that the additional capacity in the grid circuit, which here generally outweighs the static capacities, always behaves as an extra capacity in the plate circuit of the preceding stage; the load in the anode circuit of any stage is therefore dependent on the anode circuits and amplifying properties of subsequent stages. On this account it is only possible to work out the exact conditions by starting with the anode circuit of the *last* valve and calculating *backwards* stage by stage. This is especially true for resistance amplifiers, but really applies to amplifiers of all types.

The feed-back from the anode is clearly of extreme importance also in designing resistance-coupled high-frequency amplifiers. *The appearance from this cause of a resistance in the grid circuit is of very special importance in the design of circuits containing an aperiodic high-frequency amplifier.* If there is a tuned circuit on the input side of such an amplifier, as is the case in the majority of the circuits so far published, then the damping of this circuit will be very considerably increased by this additional resistance. To give a numerical idea of the magnitude of this effect, it may be mentioned that in an aperiodic high-frequency amplifier designed to operate on the broadcast band of wavelengths, the real component has a value of the order of 10,000 ohms or less. The realisation of this fact has a very important bearing on the improvement of the selectivity of receivers with aperiodic high-frequency amplifiers, and this point will be gone into in a later communication.

There often occurs in practice the case of an inductive load in the plate circuit. In this case the feed-back from the anode results in the appearance in the grid circuit of a negative real component; that is, a negative ohmic resistance. This leads to self-oscillation as soon as it outweighs the total positive resistance in the grid circuit. This case of inductive load is especially prominent when working with a sharply tuned high-frequency amplifier, for here, as already mentioned, detuning to a very small extent suffices to make the anode circuit inductive. When self-oscillation occurs in these amplifiers as a result of the inductive load it is on this account not possible to obtain stability by an apparently accurate adjustment to resonance. The tendency to oscillation can only be overcome when the feed-back from the anode is cancelled by applying one of the well-known neutralised circuits. The same considerations hold, as need hardly be remarked, for low-frequency amplifiers, in which self-oscillation can also occur as a result of inductive anode impedances.

Further Effects of Stray Capacities.

So far the stray capacities have only been considered with reference to an amplifying stage embodying a three-electrode valve. In the case of the four-electrode valve we must take into consideration, besides the three capacities mentioned, the capacities between the second grid and the other electrodes. It is possible, with the help of these extra capacities to introduce further effects into the grid circuit and thus, by using special circuits, to attain a partial or complete compensation of the effects already discussed. Alternatively, it is possible to make use of the screening-grid arrangement to reduce considerably the anode-grid capacity. The self-capacities of the windings in choke and transformer-coupled amplifiers must be regarded as really harmful, for their chief effect is to increase the grid-cathode capacity of the stage to which they are connected.

---

* *See* M. v. Ardenne and W. Stoff, "Die Berechnung der Scheinkapäzitaten bei Widerstandsverstärkern," *Jahrbuch*, Part 3, Vol. 30, 1927; and M. v. Ardenne and W. Stoff, "On the Values and the Effects of Stray Capacities in Resistance-coupled Amplifiers," *Proc. I.R.E.*, No. 11, Nov., 1927.

Capacities which arise, as the result of unsuitable wiring, between the grids of valves which do not follow one another directly, must be regarded as especially dangerous, on account of the marked reaction effects to which they give rise. These effects are stronger than those derived from a single stage on account of the much higher alternating voltages that are carried back. Owing to the addition of successive phase-displacements self-oscillation can arise in this way even from capacitative anode circuits ; in multi-stage amplifiers especially capacities which amount to no more than a fraction of a micro-microfarad but which act as the coupling between the input and output sides of the amplifier, may often lead to a self-oscillation. In amplifiers with the stages built as separate units stray capacities of the last-mentioned type can easily be avoided by screening.

These capacities cause special difficulties in the construction of multiple valves, where great care must be taken on this account in the construction of the different stages. On the other hand, the compact construction of the circuit in multiple valves offers the advantage that the capacities, and with them the feed-back from the anodes, can be enormously reduced.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Screened Grid Valves.

To the Editor E.W. & W.E.

SIR,—May I thank Herr Von Ardenne for so courteously calling my attention to the reference made in his book to the possibility of utilising the ***negative slope*** of screen grid valves in amplifiers. Unfortunately, I have not had an opportunity of reading the book in question, but I gather from the quotation given that, at the time of writing, Herr Von Ardenne was more concerned with avoiding the region in question than with its utilisation.

As regards the latter part of his letter, I am glad to find myself in agreement with so distinguished a worker. More recent experiments of mine, which were confined to low-frequency conditions, bring out the fact that quite uniform amplification is obtainable when rather high resistances are employed. There are, indeed, other valuable applications of the method to which, however, this letter is hardly the place to refer.

JOHN J. DOWLING.

Short-wave Aerial Systems.

To the Editor, E.W. & W.E.

SIR,—In the Editorial in the June issue, the expression for the sending end impedance of an aerial is given as

$$\sqrt{\frac{L}{C}} \cdot \frac{1}{j \, . \tan wh\sqrt{L \, . \, C}}$$

This expression can be derived very simply by the method given in the article on "Short-wave Aerial Systems" in the same issue.

Thus, if Fig. 8(*d*), page 310, represents the conditions at a distance *h* from the free end of the aerial, we have

$$D_2\hat{B}_2A_2 = \frac{1}{2}D_2\hat{C}_2A_2 = \frac{1}{2} \cdot \frac{4\pi h}{\lambda}$$

$$= \frac{wh}{v} = w \, . \, h \, . \sqrt{L \, . \, C}$$

The sending end impedance is

$$\frac{\overline{V_2}}{\overline{I_2}} = R_0 \frac{\overline{A_2B_2}}{\overline{A_2D_2}} = \sqrt{\frac{L}{C}} \; \frac{1}{j \tan wh\sqrt{L \, . \, C}}.$$

E. GREEN.

Poldhu, Cornwall.

On the Equivalent Inductance and Capacity of an Aerial.

To the Editor, E.W. & W.E.

SIR,—It is evident from Prof. Howe's July editorial that we are at cross purposes. I have found an approximate value for the equivalent inductance and capacity of an aerial which, when any loading inductance is added, will give approximately the same resonant frequency as when the same loading inductance is added at the foot of the aerial. Prof. Howe, after stating this test of equivalence in his June editorial, deduced a theoretical value which is applicable when the aerial is not loaded, and in his July editorial he obtains, for a loaded aerial, a value which is a function of the loading inductance and not a characteristic of the aerial itself.

I realise a fixed value which is exact for all values of loading inductance cannot be obtained, and I have no quarrel with Prof. Howe's results as deduced from the definitions he uses, though I am not convinced that his definitions would be universally accepted.

My standpoint, however, is simply this: that the formula

$$\omega_1 L_x = \sqrt{L/C} \cot \omega_1 h \sqrt{LC} \quad .. \qquad .. \quad (1)$$

can be replaced by an approximate formula of the type

$$\omega_1(L_1 + L_x) = 1/\omega_1 C_1 \quad .. \qquad .. \quad (2)$$

where L_1 and C_1 are *constants*, and functions of L and C only. If, for a given frequency ω_1, the necessary added inductance as calculated from equation (1) is L_x, and as calculated from equation (2) is (say) L'_x, then by making

$$L_x \doteqdot L'_x \text{ when } \omega_1 \longrightarrow 0 \quad (\textit{i.e.}, \text{ when } L_x \longrightarrow \propto)$$

and by making the equations have the same root when L_x and $L'_x = 0$, we deduce the values

$$L_1 = hL/2.46 \text{ and } C_1 = hC.$$

Furthermore, these values of L_1 and C_1 make L'_x approximately equal to L_x for *all* values of ω_1: it can be shown that the maximum absolute error in L'_x is only 0.073 hL, and this occurs when ω_1 is zero or when the resonant wavelength is infinite.

The fact that Prof. Howe said there is "no special merit" in the above value of L_1 "beyond the fact that the corresponding value of the equivalent capacity is simply hC" and the fact that Prof. Howe continues to advocate values of L_1 and C_1 which are of little use for practical calculations, seemed to make these further comments desirable.

L. S. Palmer.

The College of Technology,
Manchester.

[Dr. Palmer's statement that formula (1) can be replaced by an approximate formula of type (2) where L_1 and C_1 are constants was not only disproved but a curve was given on page 359 showing how greatly L_1 and C_1 varied. Moreover, we showed that the value $L_1 = hL/2.46$ was only deduced by assuming that $C_1 = hC$,—admittedly a very convenient assumption, but with no more scientific basis than the assumption that $C_1 = 0.9\ hC$ or $1.1\ hC$. As, however the letter raises no point which was not completely answered in our July editorial we do not propose to pursue the matter further. We have just received for review a copy of Hund's "Hochfrequenz Messtechnik" (2nd edition) in which we find 18 pages (403 to 421) devoted to this subject. We commend them to Dr. Palmer and feel sure that after studying them he will alter his opinions as to the general acceptance of our definitions and as to the practical utility of the formulæ based on them.—Ed.].

BOOK REVIEW.

An Investigation of a Rotating Radio Beacon. By R. L. Smith - Rose and S. R. Chapman, pp. vii.+45. H.M. Stationery Office. Price 2/3 net.

This is issued as Special Report No. 6 of the Radio Research Board, and consists of an account of experiments carried out on an experimental rotating loop beacon transmitter erected at Fort Monckton, near Gosport. The beacon was of the type used by the Air Ministry and consists of an ordinary valve transmitter with a loop aerial, the loop being rotated at a uniform rate. Any receiver can be used to pick up the signal which will vary in strength between a maximum and zero as the loop rotates; a characteristic signal is emitted when the direction of the loop is north and south, and by carefully observing the time which elapses between this signal and the zero or minimum the observer can determine his direction with respect to the beacon. The object of the investigation was to determine the reliability of the bearings under various conditions, especially for marine navigation purposes. The system has the great advantage that one only requires an ordinary wireless receiver and a suitable watch; it is, therefore, of special interest to know that as the result of a series of observations carried out in ships under sea-going conditions, it has been found that the results are as accurate as those given by the other methods under the most favourable conditions.

Difficulty was experienced in maintaining a uniform speed of rotation, due to fluctuations in the supply voltage. This was overcome by a somewhat elaborate system employing an electrically maintained tuning fork driving a phonic motor geared to the beacon spindle. This was found to exercise sufficient control to maintain the speed constant provided the supply voltage did not vary too much from the normal value. Any variation was indicated by a stroboscope employing a Neon lamp operated from the tuning fork.

A great amount of experimental work was done with the object of discovering and, if possible, removing the cause of the lop-sidedness of the figure-of-eight polar radiation curve. The maxima were unequal and the zero on one side was replaced by a minimum value.

Although a metal wire screen around the transmitter equalised the minima it did not make them sharp, and the improvement was doubtful. It seems probable that the defects were due to some extent to the site on the edge of a sheer drop of 25 feet to the sea.

The beacon had a 6-turn frame 5 feet square, carrying a current of 40 amperes at a wavelength of 525 metres. Oversea reliable bearings can be obtained up to 50 miles by night and up to 100 miles by day, but bearings can be obtained at longer ranges with an accuracy depending on the care of the observer, who should take the mean of a number of observations to minimise the effect of night and observational errors.

In an appendix the authors give a theoretical analysis of the effect of currents set up in a tuned aerial in the neighbourhood of the transmitter. There appears to be something wrong with formula (2), however, which makes the current set up in the aerial depend only on the field strength and resistance, without any reference to the height of the aerial.

The pamphlet should be studied by everyone interested in the applications of wireless telegraphy to navigation. Its results hold out every promise that the rotating beacon will prove of great practical utility.

G. W. O. H.

A New Idea for a Detector Valve.

Y. B. F. J. GROENEVELD, Balth. v.d. Pol and K. Posthumus have shown that the grid current detection properties of a receiving valve depend almost entirely upon the grid current characteristics and the constants of the grid circuit. Measurements have shown that the anode voltage has but little influence.

The grid current characteristics can be represented substantially by an exponential function of the form

$$i_g = i_{g0}\epsilon^{\frac{V_g - V_{g0}}{V_T}}$$

where i_g = grid current,
V_g = grid voltage,

i_{g0} and v_{g0} = constants, which depend on each other, and V_T = the voltage increase required for a multiplication of the current by ϵ. The authors call this voltage the *temperature voltage*.

It thus appears that the slope of the grid current curve, logarithmically plotted, is exclusively determined by the temperature voltage. This temperature voltage is indicated by

$$V_T = \frac{kT}{e}$$

where k = constant of Boltman,
T = absolute temperature,
e = charge of electron.

The slope of the grid current curve, logarithmically plotted, is thus entirely determined by the temperature of the filament. With equal filament temperatures the nature of the material used for the filament has no influence on the detecting properties.

The experimental shape of the grid current characteristic, as described by the authors, is based on Maxwell's law of velocity distribution.

For oxide filaments the temperature voltage has a value of about 0.1 V. For thoriated filaments the average temperature voltage is 0.18 V. and for tungsten 0.25 V.

It can be calculated that the detection

$$\Delta V = \frac{1/4\, E_0^2}{V_T}$$

where E_0 = amplitude of the A.C. voltage applied.

This formula only applies for small values of E_0 $\left(\frac{E_0}{V_T} \ll 1\right)$ and for large values of the grid leak resistance $\left(\frac{1}{R} \ll \frac{di_g}{dv_g}\right)$.

From this it follows that for the *detection of weak signals* valves with a small temperature voltage, *i.e.*, with a low filament temperature, are an advantage, as the detection will be strongest with slowly moving electrons.

A filament emits electrons, partly with large, partly with small velocities. If it were possible to separate the electrons with small velocities and use them for detection, a device possessing considerably more sensitive detecting properties than a normal valve would be obtained.

Mr. K. Posthumus, of Messrs. Philips' Laboratories, Eindhoven, has suggested the idea of effecting this separation of electrons by means of a magnetic field. Under the influence of such a field the slow electrons will be deflected to a greater degree than the swift ones and by conducting these slow electrons through a separate grid, it will be possible to increase materially the detecting properties of a valve.

THE NATIONAL RADIO EXHIBITION, OLYMPIA,
SEPTEMBER 22nd to 29th, 1928.

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

A TRANSMITTER-MODULATING DEVICE FOR THE STUDY OF THE KENNELLY-HEAVISIDE LAYER BY THE ECHO METHOD.—Tuve and Dahl. (*Proc. Inst. Rad. Eng.*, June, 1928, V.16, pp. 794–798.)

The importance is emphasised of very short duration and proper spacing for the peaks, and objections to the original modified A.C. modulations are pointed out. The method now described for modulating the transmitter depends on the very sharp, widely and non-uniformly spaced pulses produced in a "multivibrator" two valve circuit (Abraham and Bloch), when this is used in an unbalanced condition. Examples of reflections obtained by this method are given. The non-uniformity of spacing is useful in the identification of the separate peaks.

NOTE ON TOTAL REFLEXION OF ELECTRIC WAVES AT THE INTERFACE BETWEEN TWO MEDIA.—H. M. Macdonald. (*Proc. Royal Society* July, 1928, No. A, 783, pp. 523–525.)

In a previous communication (*ibid*, A, Vol. 108, p. 386) it was assumed that when total reflexion takes place at the interface between two media, the electric force in the disturbance in the second medium is in the plane of the wave-front; it may be shown that it is impossible in this case to satisfy the condition that the electric and magnetic forces are both in the wave-front in the second medium. The object of the present communication is to investigate the disturbance in the second medium, and to obtain the changes of phase in the reflected waves in the first medium.

ZUR THEORIE DER AUSBREITUNG ELEKTROMAGNETISCHER WELLEN LÄNGS DER ERDOBERFLÄCHE (The Propagation of Electromagnetic Waves over the Earth's Surface).—R. Weyrich. (*Ann. d. Phys.*, 19th March, 1928, V. 85, pp. 552–580.)

Propagation from a vertical Hertz dipole is considered, in a parallel slab of dielectric between perfectly conducting planes. The dielectric slab is assumed to have S.I.C., permeability and conductivity.

SUR LES PROPRIÉTÉS DIÉLECTRIQUES DES ÉMULSIONS GAZEUSES (Dielectric properties of gaseous emulsions).—C. Pawlowski. (*Comptes Rendus d.l. Société Polonaise de Physique* No. 6, 1926, pp. 44–55; abstracted in Phys. Berichte, 15 June, 1928.)

By gaseous emulsions are meant suspensions of small drops of liquid in a gas. If these drops have no electric charge, the dielectric constant can be calculated by Wiener's formula. Actual dielectric tests on artificially produced mists (including a water mist) show that the formula does not then apply: it allows neither for the structure of the mist nor for the influence of the frequency of the A.C. field used for the measurement. The dielectric constant decreases with increasing frequency and with increasing amplitude.

LA PRÉCISION DES MESURES ET SON CONTRÔLE DANS L'OPÉRATION DES LONGITUDES MONDIALES (The Precision of Measurement, and its Control, in the Determination of World Longitudes).—A. Lambert. (*Comptes Rendus*, 21st May, 1928, V. 186, pp. 1425–1427.)

Curves are given which suggest variations in the time of long distance, long wave wireless communication amounting to as much as 0.001 sec. over distances of the order of 12,000 kms. The author says however that the value for velocity of propagation derived from these observations is so low (mean $V = 247{,}000 \pm 9{,}000$ km./sec.) as to suggest some systematic error in registering the arrival of the waves.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

SOME ELECTROPHYSICAL CONDITIONS DETERMINING LIGHTNING SURGES.—H. Norinder. (*Jour. Franklin Inst.*, June, 1928, V. 205, pp. 747–765.)

A paper describing recent work done in Sweden, and the conclusions drawn from it. Subheadings, with extracts, are as follows:

(1) Distribution of charge and calculation of field force. Certain assumptions have to be made: with these, the calculated field force, with the earth's surface insulated, becomes about 60 kV/m. If the surface is supposed to be quite conducting, Kelvin's method of images leads to a doubling of this value. Direct observations have led the writer to find gradients of 100 to 150 kV/m.

(2) Dimensions of the field regions. The writer concludes that the thunder-cloud is formed of a few large regions of different polarity rather than of a great number of smaller regions. It has been proved that the greater number of discharges take place within the internal parts of the thunder-storm atmosphere, only a small proportion passing from cloud to earth or from earth to cloud. Lightning surges in transmission lines are generally positive, though some discharges can cause double polarity.

(3) The regions discharged by lightnings. A very pronounced limitation has been found to the size of these regions, agreeing with the high values found for the field force.

(4) Research on the discharging rate of lightning: by the use of a special cathode-ray oscillograph, time variations of an order of magnitude of microseconds can be recorded. The ray only records when a suitable voltage or current is applied to the

deflecting circuits, the instrument thus being independent of the time of arrival of the phenomenon to be recorded. This is attained by a special device which makes the ray itself act as a relay. Lightning discharges in an aerial have thus been recorded, and examples are given. Two types of discharge are recognised, one very slowly discharging (probably taking place mainly between internal parts of the cloud) and one rapidly discharging (earth-to-cloud or *vice versa*); but sometimes the rapid may occur within the cloud itself. This may especially be the case for secondary lightning initiated by the ionisation processes of primary slowly moving lightnings. Sometimes a super-imposed high frequency (of an amplitude of only a few per cent. of the total field variation) is observed on the usual non-oscillatory discharges. The main part of the statics produced in a wireless receiver is due to this high frequency, whose period is estimated to vary between 10 and 30 microsec.

SUR L'IONISATION INTENSE DE L'AIR DANS LES LIEUX FRÉQUEMMENT FOUDROYÉS (Intense ionisation of the air in spots frequently struck by lightning).—Dauzère and Bouget. (*Comptes Rendus*, 18 June, 1928, V. 186, pp. 1744-1746.)

In a former paper (*C.R.*, 4 June, 1928), the authors described tests made by them concerning the predilection of lightning for certain spots, and showed that these spots are not necessarily prominent points, but that the choice depends on the geological composition of the ground. They found that compact, chalky soils enjoy a very great security from lightning, whereas siliceous rocks and soils enclosing minerals are often struck. In the present paper, the authors mention tests to support their derived theory—that the chosen places are those where the air near the ground is more ionised than elsewhere. These tests (with the Elster and Geitel apparatus) showed that spots exist where the ionisation of the air near earth is *constantly* greater than in neighbouring spots at the same altitude and under the same physical conditions; that this depends on the geological constitution of the soil; and that the more highly ionised spots are particularly liable to be struck by lightning. Among the suggested practical applications of this knowledge is the proposal that the use of the electrometer should help in geological exploration.

THE UPPER ATMOSPHERE.—J. Bartels. (*Naturwissenschaften*, 4th May, 1928.)

A summary of our present knowledge, based on observations of meteors, luminous high clouds, auroræ, ozone, long distance propagation of sound, terrestrial magnetic variations, and radio propagation.

ÉTUDE DES FLUCTUATIONS NOCTURNES DE L'OZONE ATMOSPHÉRIQUE (Night fluctuations in atmospheric ozone).—D. Chalonge. (*Comptes Rendus*, 25th June, 1928, V. 186, pp. 1856-1858.)

The author's measurements lead him to the following conclusions: The higher atmosphere never contains less ozone at night than by day; the thickness of the ozone layer at night varies little from a mean value which (at Paris) is 335 hundredths of a millimetre (reduced to N.T.P.): *i.e.*, it presents no seasonal variation, at any rate for the period studied (October 1927—April 1928); and the author's final conclusion is that to account for the creation and the fluctuations of the ozone at high altitude, other causes besides ultra-violet solar radiation must be looked for.

OBSERVATIONS ON THE HEIGHT OF THE OZONE IN THE UPPER ATMOSPHERE.—Götz and Dobson. (*Nature*, 14th July, 1928, p. 79: from Royal Society Meeting.)

Measurements of the height over Arosa (Switzerland) show that it is greatest when the amount is large and least when the amount is small. There is also evidence of an increase of height from autumn to spring. The average height seems to be between 35 and 40 km.

ON THE QUANTITY OF ELECTRICITY DISCHARGED IN A LIGHTNING STROKE.—A. W. Simon. (*Proc. Nat. Acad. Sciences*, June, 1928, V. 14, pp. 458-460.)

Calculations based on the experimental work of Norinder lead the author to conclude that the order of magnitude is probably 10 coulombs.

THE RAMAN EFFECT AND THE SPECTRUM OF THE ZODIACAL LIGHT.—L. A. Ramdas. (*Nature*, 14th July, 1928, V. 122, p. 57.)

The Raman effect, originally found in the case of liquids, has been obtained by the writer for the vapour of ether. The same special spectrograph also photographed the spectrum of the zodiacal light, no trace being found of light of wave-lengths longer than about 5,000 A.U. This indicates that the scattering material producing the zodiacal light is diffused in atomic or molecular condition, and the writer suggests that the production of modified frequencies by the Raman effect may account for the observed weakness of polarisation of the light.

CARRIERS OF ELECTRICITY IN THE ATMOSPHERE.—A. M. Tyndall. (*Nature*, 7th July, 1928, V. 122, pp. 16-17.)

Substance of a recent lecture on the study of ion-motion in an electric field.

THE CORRELATION OF SOLAR AND TERRESTIAL MAGNETIC PHENOMENA.—S. Chapman. (*Nature*, 23rd June, 1928, V. 121, pp. 989-991.)

SUR LA LOI DE VARIATION DE DENSITÉ DE L'ATMOSPHÈRE EN FONCTION D'ALTITUDE (The Law of Variation of the density of the atmosphere as a function of the altitude).—Esnault-Pelterie. (*Comptes Rendus*, 2nd July, 1928, V. 187, pp. 55-56.)

The author derives a formula which he claims allows for the first time the accurate determination of altitude by simple measurements of temperature and pressure, at any rate for layers of sufficient height.

LA PRÉVISION DES CYCLONES DE LA MER DES ANTILLES ET DU GOLFE DU MEXIQUE (Forecasting cyclones).—Laforest Duclos. (*Comptes Rendus*, 2nd July, 1928, V. 187, pp. 17–19.)

The author claims that all the phenomena of our atmosphere are due to the *combined* action of solar heat and the attraction of Sun and Moon. He arrives at a simple formula for f (daily cyclone-tendency); if this exceeds a certain value, a cyclone occurs.

RADIOAKTIVE NIEDERSCHLÄGE AUF HOCHANTENNEN (Radioactive deposit on high antennæ.)—F. Schindelhauer. (*Phys. Zeitschr.*, 15th July, 1928, V. 29, pp. 479–487.)

ÜBER DIE HYPOTHESE, DASS DIE HÖCHSTEN ATMOSPHÄRENSCHICHTEN DURCH BETA-STRAHLEN ERWÄRMT WERDEN (The hypothesis that the highest layers of the atmosphere are heated by β-rays.)—H. Petersen; reply by W. Anderson. (*Phys. Zeitschr.*, 15th July, 1928, V. 29, p. 492–493.)

PROPERTIES OF CIRCUITS.

SUR UNE NOUVELLE MÉTHODE D'AMPLIFICATION DES COURANTS ALTERNATIFS À HAUTE FRÉQUENCE (A new method of amplifying H.F. currents).—J. Bethenod. (*L'Onde Élec.*, June, 1928, V. 7, pp. 261–262.)

The method described was patented by the author in 1924. Since then, he says, somewhat similar proposals have been made by the younger Van de Pol (*cf. E.W. & W.E.*, June, 1926). The method depends on the fact that if an oscillating circuit is made up of a condenser C and inductance L both varying periodically but in such a way that always $CL = C_0L_0$, it must behave as if it were a circuit with constant capacity C_0, constant inductance L_0 and an apparent resistance

$$\frac{L_0\left(R+\frac{dL}{dt}\right)}{L},$$

where R is the constant ohmic resistance. Now, if L varies periodically with a frequency $\frac{\omega}{2\pi}$ (much less than the natural frequency of the circuit) and if the quantities are chosen suitably, the apparent resistance will periodically take on a negative value during a certain fraction of the period; so that impressed waves tuned to the natural frequency of the circuit will grow indefinitely during this part-period, and an important effect of amplification will be obtained.

THE IMPEDANCE ADJUSTING TRANSFORMER.—C. T. Burke. (*Rad. Engineering*, May, 1928, V. 8, p. 18.)

"A little consideration will show that if the primary impedance of this transformer is equal to the tube impedance and if the secondary impedance matches the load impedance, one-half the voltage existing in the plate circuit will be expended in heating the plate. It is obvious, then, that the primary impedance should be several times that of the tube." Perusal of the above statement (which he says is typical of the mental haze surrounding the subject) prompts Mr. Burke to write, with an amusing touch, an explanation of the function of transformers designed to match impedances: deriving first the equation for maximum energy transfer:—Turns Ratio = square root of the ratio (Primary Impedance) to (Secondary Impedance): and then showing how this must be combined with other factors in designing the transformer.

THE THEORY OF WAVE FILTERS CONTAINING A FINITE NUMBER OF SECTIONS.—H. A. Wheeler. (*Phil. Mag.*, July, 1928, V. 6, pp. 146–174.)

THE PHENOMENON OF BLOCKING OF POTENTIAL OF AN INSULATED GRID.—S. A. Obolensky. (*Teleg. i. Telef. b.p. Nichny-Novgorod*, June, 1928, V. 9, pp. 259–273.)

TRANSMISSION.

COMPLEX TRANSMITTING ANTENNÆ.—Turlygin and Ponomarev. (*Teleg. i Telef. b. prov., Nichny-Novgorod*, June, 1928, V. 9, pp. 281–303.)

RÖHRENGENERATOR GROSSER LEISTUNG FÜR SEHR KURZE ELEKTRISCHE WELLEN (A Power Valve Generator for very Short Waves).—H. Wechsung. (*Zeitschr. f. Hochf. Tech.*, June, 1928, V. 31, pp. 176–183.)

The circuit on which these theoretical and experimental investigations are based was described by A. Esau (E.T.Z., V. 47, No. 11, 1925). On the information thus obtained, two short wave transmitters have been constructed. The smaller delivers 150 watts to the aerial for telegraphy, 60 watts for telephony, with an efficiency of about 38 per cent. The larger gives 700 and 300 watts respectively, with an efficiency of 35 per cent. Both sets work on 2.8 to 6 metres. Telephony is by grid control, which was found to be the best method. Reception at a distance was by the short-wave receiver described by O. Cords (same journal, January and February, 1928).

TECHNICAL CONSIDERATIONS INVOLVED IN THE ALLOCATION OF SHORT WAVES (frequencies between 1.5 and 30 megacycles).—L. Espenschied. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 773–777.)

The paper begins with a chart which is believed to represent the consensus of present knowledge as to the approximate relation of Optimum Frequency to Distance of Communication, for Short Waves ranging from 10 to 200 metres, and distances 0—7,000 miles; curves for night, day and intermediate periods are shown. For tabulating purposes, the following three bands can be derived from this chart: 200—50m., for distances up to 1,000 miles at night; "regional" in its service range: the shorter waves may cause interference over intercontinental distances at night; 50—20m., "regional" for the daylight portion of the globe but may include practically the entire hemisphere in darkness; and 20—10m. (the shorter limiting wavelength being somewhat uncertain), appearing to be world wide, extreme distances being reached especially over the daylight hemisphere. The International Frequency Allocation (starting 1st January, 1929) is tabulated, and on the same table appear the ideal limiting numbers of channels for telegraph and telephone (channel spacings 1,000 and 10,000 cycles respectively) and also estimated figures based on present general practice. The ratio ideal/present varies from 70 for the shortest wavelengths to 5 for the longest (telegraph), for reasons which are briefly outlined.

BEAM TRANSMISSION OF ULTRA-SHORT WAVES.—H. Yagi. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 715–741.)

Part I. of this paper is devoted to a description of various experiments on wavelengths all below 5 metres and the majority below 2m. Curves are given to show the effect of the earth (the energy transmitted increases when the height of receiver *and* transmitter is increased, no limit having been yet found for this effect; but when either receiver or transmitter is kept fixed, the energy transmitted has a maximum when the other reaches about that height) and of various types of inductively excited antennæ called "wave directors" which can be combined with wave reflectors to give a very sharp beam. Such a wave "director" is an oscillating system of frequency higher than that of the wave to be transmitted; the field converges upon it, and radiation in a plane normal to it is augmented. Part I. concludes with the beam projection of horizontally polarised waves, first parallel to the surface of the earth and then with high-angle radiation. Part II. is devoted chiefly to the magnetron valves used for the production of very short wavelengths down to 12 cms. and the circuit arrangements employed (*c.f.* July Abstracts, paper by K. Okabe). With the shorter waves dealt with in this Part, sheet metal parabolic reflectors may be used. A Barkhausen single valve receiver was employed successfully as a detector on wavelengths of about 150 cms.

On 41 cms. the maximum distance at present covered was reached—1 kilometre: here a crystal detector with a 3-stage note amplifier was used. In the discussion following, the Bureau of Standards Chief of Radio Division assigns considerable importance to the work by his concluding words "I have never listened to a paper that I felt so sure was destined to be a classic."

ALLOCATION OF EUROPEAN BROADCAST WAVELENGTHS (Some New Points of View.)—S. Lemoine. (*E.W. & W.E.*, July, 1928, V. 5, pp. 386–396.)

RECEPTION.

LE PHÉNOMÈNE DE MILLER DANS L'AMPLIFICATION HAUTE FRÉQUENCE (The "Miller" effect in high frequency amplification.)—G. H. d'Ailly. (*Q.S.T. Franç.*, July, 1928, pp. 12–19.)

The writer disapproves of the mathematical treatment which Miller has given to the phenomenon which bears his name, and proceeds to give his own analysis of the effect. The article is to be continued.

LES "SUPER-RÉACTIONS" (Super-regeneration).—P. David. (*L'Onde Élec.*, June, 1928, V. 7, pp. 217–259.)

This paper may be divided as follows:—(I) Definition. (II) Study of an oscillating circuit in function of its resistance-values; (*a*) resistance constant and not zero; (*b*) resistance zero; (*c*) resistance variable as a function of time. (III) Application. Method of action. Three varieties:—(1) Super-regeneration *A* or telephonic (the original "Armstrong circuit.") (2) Super-regeneration *B* or stroboscopic: negative resistance is large to obtain maximum amplification but without reaching saturation point: the free oscillations are not extinguished entirely between two periods, their residue causing beats with the signal: these beats are themselves supersonic, but the stroboscopic effect produces audible whistles. This method is therefore applicable to continuous wave reception, and is particularly useful for short wave working because of its ease of adjustment compared with heterodyne or autodyne methods. (3) Super-regeneration *C* or anti-jamming; negative resistance reaches very high values, giving saturation; incoming continuous waves produce silence undisturbed by interference; signals produced by cutting up the continuous waves become audible together with the interference. Each of these varieties *A*, *B* and *C* is considered and illustrated by curves. The author then deals with the influence of length of wave (showing that increased frequency facilitates the action, but contradicting Armstrong's idea that the amplification grows as the square of the frequency) and then with the question of sensitivity and selectivity. Finally, he verifies his theoretical explanations of the processes involved by cathode-ray records taken with each of the varieties *A*, *B* and *C*. A bibliography of 23 items is attached.

NOTICE SUR LE RÉGULATEUR ANTI-FADING.—(*Rad. Revue*, June 1928, v. 7, p. 692.)

The de Bellescize Anti-fading regulator depends on a relay (working, for example, by the rectified detector-current) which controls the amplification by adjusting the grid voltages.

ENDVERSTÄRKERPROBLEME.—B. D. H. Tellegen. (*Zeitschr f. Hochf. Tech.*, June, 1928, V. 31, pp. 183–190.)

A complete translation into German of the original Dutch paper (see July Abstracts).

SOME CORRELATIONS OF RADIO RECEPTION WITH ATMOSPHERIC TEMPERATURE AND PRESSURE.—G. W. Pickard. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 765–772.)

Night reception and temperature at the receiver are found to be directly related, maximum reception being associated with maximum temperature. This is the reverse of the relation previously found by Austin for day reception, where falling temperature improved reception; and is therefore another case of the already-established inverse relation of night to day reception. The temperature effect appears to be local to the receiver, for no definite relation was found between temperature at the transmitter and reception.

A correlation between night reception and pressure was also found, signal strength increasing as areas of low pressure passed over the receiver, and decreasing with the passage of high pressures. All these relations do not hold over long periods during which seasonal changes can intervene; and the author points out that as both temperature and pressure are related to solar activity, it is not safe to assume that the correlations are purely those of cause and effect.

On the Distortionless Reception of a Modulated Wave and its Relation to Selectivity.—(*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 848–850.)

Further discussion on the Vreeland paper (see May abstracts). It is mentioned that if the coupling is made to increase at a rate slightly less than as the first power of the frequency, not only is the selectivity improved, but the amplifications at high and low frequencies are equalised. This can be done by employing combinations of capacitive and inductive couplings. Such an arrangement is believed to be more nearly ideal than that discussed by Vreeland.

Loose Coupling (Some notes on two-circuit receivers.)—" Radiophare." (*Wireless World*, 4th June, 1928, V. 23, p. 10.)

A defence of the " old fashioned " variably coupled and separately tuned aerial circuit, on the grounds of its increased signal strength for a given selectivity.

The Output Stage and the Pentode.—N. W. McLachlan. (*Wireless World*, 11th, 18th and 25th July, 1928, V. 23, pp. 30–33, 77–80, and 113–115.)

Will the pentode replace its 3-electrode predecessors as a loud-speaker valve ?

Switch-over Three.—H. F. Smith. (*Wireless World*, 4th and 11th July, 1928, V. 23, pp. 2–6 and 34–37.)

Full constructional details of an efficient switching scheme giving continuous tuning from 250 to 2,200 metres. It is stated that the loss due to switching, compared with a fixed band receiver and in terms of H.F. voltage across detector grid circuit for a steady input, is only 10 per cent.—which from the point of view of audibility is negligible.

The Pentode.—W. I. G. Page. (*Wireless World*, 4th July, 1928, V. 23, pp. 7–9.)

The working principles of the screened grid power output five-electrode valve are explained and its advantages illustrated by curves (*cf.* " Eindversterkerproblemen " in July abstracts).

System for Combating Effects of Static.—E. A. Tubbs. (*E.W. & W.E.*, July, 1928, V. 5, pp. 378–379.)

The Use of Alternating Current for Heating Valve Filaments.—C. W. Oatley. (*E.W. and W.E.*, July, 1928, V. 5, pp. 380–384.)

VALVES AND THERMIONICS.

Frequency Variations of the Triode Oscillator.—D. F. Martyn. (*Phil. Mag.*, July, 1928, V. 6, pp. 223–228.)

The writer refers to his paper with the same title in Phil. Mag., November, 1927, and maintains that his mathematical theory there developed (which takes account of the flow of grid current) is the only one which satisfactorily accounts for the large frequency variations observed by various workers, and on a particularly large scale by the writer himself; provided, at least, that the resistances present are not large and the frequency is not too high. To obtain constant frequency, grid-current is to be eliminated; this cannot be done merely by increasing the negative grid bias; other optimum conditions must be observed, and a small condenser in series with the grid coil (automatically adjusting the grid bias) is an advantage. Stringent tests on such an oscillator showed that the frequency remained constant to one part in 100,000 even when the filament current was deliberately varied, and to a much higher degree when the filament current remained steady.

An Empirical Thermionic Emission Formula.—V. I. Volynkin. (*Phys. Berichte*, 15th June, 1928, from the Russian.)

The author proposes, for practical use, to modify the formula $J = A \, . \, T^{a} e^{-\frac{b}{T}}$ (where a lies between -1 and 2 according to the various theories) by putting $a = 0$. The formula then becomes $J = A_0 \, . \, 10^{-\frac{a}{T}}$, which gives the same accuracy as the original. For Tungston, $A = 1.48 \times 10^9$ Amp./cm.^{2} and $a = 24{,}400$ abs.

Very Short Undamped Waves in a Receiving Valve.—D. Rozanskij. (*Phys. Berichte*, 15th June, 1928, p. 1093, from the Russian.)

The author obtains waves down to 10 cm. by the application of moderate grid potentials, in ordinary receiving valves. Still shorter waves can be produced by enclosing the oscillating inductance inside the valve container (*cf.* July Abstracts, paper by E. Pierret—who however only got down to 14 cms.).

Die Stromverteilung in Dreielektrodenröhren . . .—H. Lange. (*Zeitschr. f. Hochf. Tech.*, June, 1928, V. 31, pp. 191–196.)

Final part of the paper abstracted in July and August numbers. Section E deals with practical applications: (1) double-grid valves; (2) transmitter valves, and (3) investigation of secondary emission. Section F deals with contact-potentials, which by the help of current-distribution measurements can be determined with an accuracy (± 5 mV.) far greater than by Schottky's method using the starting current, and with much greater ease. The author however admits that complete absence of space charge is essential, so that very small currents (about 10^{-7} amp.) and very high vacuum must be used. Section G is devoted to this latter point.

FOUR-ELEMENT TUBE CHARACTERISTICS AS AFFECTING EFFICIENCY.—D. C. Prince. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 805–821.)

In this work the fourth electrode was only used to eliminate secondary emission in order that the variation in the ratio grid current to plate current in 3-electrode valves might be studied to ascertain the laws of current division. It was thus found that in a tube having symmetrical electrodes, *i.e.*, straight wire filament, concentric cylindrical anode and cylindrical grid (made up of wires parallel to the axis) the ratio was a function of the valve geometry and quite different from that usually found in commercial design. This discrepancy appears to be due to a combination of secondary emission from the anode and unsymmetrical arrangements of grid wires and supports.

DETECTION WITH THE FOUR-ELECTRODE VALVE.—J. R. Nelson. (*Ibid.*, pp. 822–839.)

A mathematical analysis of plate rectification is given and the results applied to a screen-grid valve of type Cunningham CX.322. The screen-grid detector under proper conditions will efficiently utilise the high radio-frequency voltage obtained with the screen-grid valves used as radio-frequency amplifiers. The square law holds for large input voltages, making it practical for the detector to work power valves of the type Cunningham CX.371.

THE SCREEN-GRID TUBE.—N. H. Williams. (*Ibid.*, pp. 840–843.)

Radio-frequency amplification by means of the 3-electrode valve is usually disappointing; in resistance coupling, owing to the phase-relation of the feed-back reducing amplification, and in inductive coupling the feed-back causing self-oscillation for conditions of best amplification. In the shielded grid valve the feed-back is reduced to a negligible amount and the current through the valve is very nearly independent of the plate voltage over the working range. Under these conditions, the voltage amplification becomes the product of the mutual conductance and the load impedance. High impedance in the plate circuit is obtained by using a sharply tuned parallel circuit. With proper shielding such a circuit may be used without producing self-oscillation. At a wavelength of about 400m., amplifications of 80-fold per stage may be obtained, and more at lower frequencies. An overall amplification of more than two million-fold has been measured for a 5-stage amplifier so built that each stage was in a separate compartment of a metal box. As an example of the simplicity of calculation with the screen-grid amplifier in research, mention is made of the measurement of the charge of the electron by the shot effect. Electrons produced by thermionic emission, by photo-electric emission and by ionisation of gases were all measured in this way.

SECONDARY ELECTRONS FROM COBALT.—M. N. Davis. (*Proc. Nat. Acad. Sciences*, June, 1928, V. 14, pp. 460–465.)

The secondary emission from cobalt for low velocity primary electrons was studied. It proves to be much greater than that from any other metal yet investigated.

DIE ABGESCHIRMTEN RÖHREN (Screen-grid Valves). M. v. Ardenne. (*Rad. f. Alle*, July, 1928, pp. 290–297.)

X-ray photographs of screen-grid valves by various makers are included, and characteristic curves of the Telefunken RES.044. These various types are compared in the text. Other types are also described in a paper by N. Werner ("Modern Screen Grid Valves") in the same number.

ÜBER DIE ERREGUNG SEHR SCHNELLER ELEKTRISCHER SCHWINGUNGEN IN DER DREI-ELEKTRODENRÖHRE (The Excitation of very Rapid Oscillations in the 3-electrode Valve). —O. Pfetscher. (*Phys. Zeitschr.*, 15th July, 1928, V. 29, pp. 449–478.)

More work on the "Gill-Morrell" oscillations.

DIRECTIONAL WIRELESS.

AIRPLANE RADIOBEACON VARIATIONS OVERCOME. —(*Tech. News Bull., B. of Stds.*, June, 1928, No. 134, p. 82.)

The errors at night (*cf.* August Abstracts) have been largely overcome by replacing the slanting, trailing aerial by one consisting of a vertical 10ft. metal pole, a special new receiver enabling such a short aerial to be satisfactory. But it is said that on some of the airways the beacons will probably be spaced closer together (power being reduced) so as to allow the short range undistorted directional effect to be used.

AIRCRAFT RADIO AND NAVIGATION.—R. Gunn. (*Journ. Franklin Inst.*, June, 1928, V. 205, pp. 849–863.)

The essential engineering features of aircraft radio and the associated difficulties are discussed. Solutions of these problems are given, although no attempt has been made to describe particular equipment. Two outstanding radio aids to aerial navigation are discussed (the equi-signal radio beacon—see August Abstracts—and a "homing" device which is an application of the same principle to the aircraft receiver) and a method is described whereby these may (with sacrifice of range) be made to operate a visual indicator. A modification of the equi-signal beacon is also mentioned, in which the possible 180 degrees error is avoided by combining an aerial effect with the loop effect and altering the angle between the loops from 135 degrees to about 90 degrees. A heterodyne beacon is finally described, in which two crossed loops or other directive systems, quite uncoupled, are fed with H.F. differing by, say, 1,000 cycles. The intensity of the received beat frequency depends within limits on the product of the intensities of the two impressed oscillations, and the system produces a sharp zero signal on either side of a narrow maximum—very suitable for timing. The beacon rotates, sending a non-directional timing-signal when the sharp maximum is directed N. Complications are rather expected when an attempt is made to avoid the 180 degrees error by combining with an aerial.

Über die von Leitergebilden in der Umgebung eines Funkpeilers Rückgestrahlten Störfelder und die Verfahren zu Ihrer Kompensierung (The error-producing field re-radiated by a conducting structure in the neighbourhood of a direction-finder, and its compensation).—F. A. Fischer. (*E.T.Z.*, 12th July, 1928, V. 49, pp. 1043–1045.)

The basis of this paper has already appeared (*E.T.Z.*, 1925–26–27) in articles dealing with the correction of errors on board ship; but as the further building up of the theory and practice of such compensation is buried in nautical journals *Ann. d. Hydrographie*, 1926–27), the present paper reproduces a general survey of these articles, dealing first with the theory of the re-radiated field and then with its compensation. The paper deals throughout with a D.F. using a loop with associated vertical aerial.

MEASUREMENTS AND STANDARDS.

The Status of Frequency Standardisation.—J. H. Dellinger. (*Proc. Inst. Rad. Eng.*, May, 1928, V. 16, pp. 579–592.)

A paper by the Chief of Radio Section, Bureau of Standards, Washington.

The measurement of frequency has become of first-rank importance in reducing radio interference. This has come about through the increasing use of all available radio channels, particularly at broadcasting and higher frequencies.

While an accuracy of one half per cent. was satisfactory five years ago, accuracies a thousand times as good are now sought. Nor is it only a question of measurement; frequencies of transmitting stations must actually be held constant with very great accuracy.

The piezo oscillator is meeting the needs of this situation in large part; but commercially available oscillators, without temperature control, are generally reliable only to about 0.03 per cent.—just barely enough to meet the present U.S.A. requirement of one-half kilocycle. The Bureau and other organisations are engaged in a co-operative programme to attain an accuracy and constancy of 0.001 per cent. for the national primary standard, and it is hoped that this, and simultaneous work in other countries, will lead to a corresponding improvement in the agreement between international standards from its present value of about 0.003 per cent. Even this value is in advance of requirements for the present degree of accuracy in general practice; but it is hoped that this will be improved to a value of the order of 0.003 per cent. (*i.e.* a tenfold improvement).

Both aspirations depend very largely on the new possibilities opened up by the temperature-controlled piezo-oscillator carefully used. As regards short-wave transmission (*e.g.*, 30 metres), such H.F. channels cannot at present be spaced closer than 0.1 per cent., but it is likely that for C.W. work under the hoped-for conditions, the channel-width could be narrowed to about 0.01 per cent., and as regards longer waves, several stations could broadcast on the same frequency without heterodyne interference. A point made is that it is *not* true that highly accurate comparisons can be made by sending a quartz plate from one laboratory to another; the complete piezo-oscillator must be sent.

Another point is that even the highest accuracy is less urgent than high constancy.

A short discussion follows the paper.

Das Mass der Abweichung einer Wellenform von der Sinus-Welle (The Measurement of the departure of a waveform from the sine-wave form).—(*E.T.Z.*, 17th May, 1928, pp. 776–778.)

An argument between Benischke and Hammerer over proposals for the establishment of a "deformation coefficient" which shall serve the purposes both of Power Engineering and of Telephony, etc.

Sur le Champ Magnétique et L'Inductance d'une Spire Circulaire (The Magnetic field and the inductance of a circular helix).—P. Bunet. (*Rev. Gén. de l'Elec.*, 19th May, 1928, V. 23, pp. 853–860.)

The primary object of this paper is to expose as inexact the conclusions of C. Hering relative to the self-inductance of a circular circuit. In addition, however, it investigates the various well-known formulæ to find with what approximation they give their numerical values.

Mesure de L'Indice de Réfraction de L'Eau pour les Ondes Entretenues Courtes (Measurement of the index of refraction of water for short undamped waves).—Martey and Jones. (*Revue Scientifique*, 25th February, 1928, V. 66, pp. 119–120.)

The index of refraction is deduced from the phase-difference between two parts of the same ray, the one having travelled in air and the other through water. Each part has its own receiving circuit, and the induced E.M.F.s in these are used to obtain Lissajous' figures in a cathode oscillograph. The wavelengths used were from 3 to 7 metres, and the values obtained for the index of refraction varied between 8.4 and 9.4.

A Description of Inductances and the Calculation of the Value of Inductances of the Air Core Type.—F. F. Rider. (*Rad. Engineering*, May, 1928, V. 8, pp. 24–27 and June, pp. 50–53.)

The usual formulæ of Lorenz and Nagaoka are supplemented by special ones for spider-web, honeycomb and toroid windings. Mutual inductance is briefly dealt with. The second instalment gives curves and tables for the construction of various types of inductances.

Die Scheinbare Änderung der Dielektrizitätskonstante Technischer Isolierstoffe (Apparent variation in specific inductive capacity of insulating materials in practical use.)—P. Böning. (*Zeitschr. f. Tech. Phys.*, June, 1928, pp. 212–214.)

The theoretical S.I.C. is a constant varying only with temperature and (mechanical) pressure. In the case, however, of the most important dielectrics in practical use, there appears (sometimes very markedly) a dependence of S.I.C. on the voltage applied. The object of this paper is to show that this arises from the same facts which led the writer to propound his "Relation between Breakdown Voltage and Thickness of dielectrics" ("Breakdown Function") in 1908: namely, that conductivity in liquid and solid insulators is of an electrolytic nature; that at the surface between two media, one of which contains dissociated ions, a part either of the kations or the anions is absorbed; and that consequently there must be present in the material inter-communicating, electrolyte-filled canals. The writer derives the following equations for the relation between ϵ (the theoretical constant) and ϵ' (the actual variable value of S.I.C.) where d is the thickness of dielectric, and V the applied voltage:

$$\epsilon' = \epsilon + \frac{A}{V} \qquad (d \text{ constant})$$

$$\epsilon' = \epsilon + Bd^2; \qquad (V \text{ constant})$$

Experimental tests appear to confirm these theoretical results; at low voltages discrepancies occur which however fit in with the assumptions on which the calculations are based.

Data on the Voltage Amplification of Radio Frequency Transformers.—B. K. Osborn. (*Rad. Engineering*, May, 1928, V. 8, pp. 13–15.)

Analysis of the results obtained with testing apparatus outlined in a previous article. The transformers tested are classed as "continuous winding" if the direction of rotation keeps the same as one proceeds from the plate of the amplifier valve, through the primary, to the filament end of the secondary and through the secondary to the grid of the output valve; and as "reversed" if the direction of rotation changes as one passes from primary to secondary. Curves are given showing that the "reversed" winding gives the higher amplification at the maximum point on the curves; moreover, it gives greater selectivity. These effects are not produced in transformers so wound as to have very low capacity between the two windings. Other effects of variation in ways of winding, etc., are shown.

Ground Resistance Testing.—W. B. Craigmile. (*Elec. World*, 28th April, 1928, V. 91, pp. 861–862.)

A method of test requiring two auxiliary earths and employing a special "megger"-type ground resistance tester reading directly the required resistance.

The D.C. hand-generator provides current which after passing through the ohmmeter is transformed into A.C. for the test by means of a commutator. The P.D. across the ground under test is used to produce an A.C. which is rectified by a similar commutator and supplies the "potential" coil of the ohmmeter. Readings are independent of the speed of rotation.

The (U.S.A.) Navy's Primary Frequency Standard.—Worrall and Owens. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 778–793.)

This constant frequency source is a crystal-controlled oscillator of special design employing a circuit which is particularly rich in harmonics, over 200 of which can be used as fixed standard frequencies. After describing this, the paper gives in detail the method by which the fundamental frequency of this standard is determined in terms of Naval Observatory time to an accuracy of about one part in 100,000. The ultimate standard of frequency is therefore the mean solar day.

A Method of Wavelength Measurement by Means of Piezo-quartz.—V. S. Gabel. (*Teleg. i. Telef. b.p., Nichny-Novgorod*, June, 1928, V. 9, pp. 323–329.)

The Measurement of Choke Coil Inductance.—Wright and Bowditch. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 844–847.)

Discussion of the paper abstracted in June number. The authors are accused of various errors, and defend themselves.

SUBSIDIARY APPARATUS AND MATERIALS.

A Modern Photographic Electrograph.— R.E. Watson. (*Journ. Sci. Instruments*, May, 1928, V. 5, pp. 145–152.)

The author summarises his article as "describing a new installation for obtaining continuous photographic records of atmospheric electrical potential, in which, owing to the unique construction of the insulators, uncertainties due to defective insulation are reduced to a negligible amount. The capacity of the system is small, and rapid changes of potential are well registered, while the sensitiveness is capable of variation through fairly wide limits."

The Quadrant Electrometer.—J. F. Sutton. (*World Power*, June, 1928, V. 9, pp. 319–326.)

The author classifies the various kinds of measurements for which the instrument is specially suitable by reason of its characteristics, and investigates the degree of accuracy which may be expected.

Deux Exemples de Montages qui font Intervenir la Variation des Charactéristiques d'un Appareil Récepteur ou de Mesure (Two examples of methods of connection which introduce variation of the characteristics of a receiving or measuring instrument).—L. Cagniard. (*L'Ode Élec.*, April, 1928, pp. 162–166.)

The author proposes to show how a quadrant electrometer, which when used idiostatically is an instrument of very mediocre sensitivity, can be made into one of enormous sensitivity by using the fact that its capacity increases with its deflection. In the present article, however, he only leads up to the subject by describing how this property can be used to convert a quadrant electrometer into a "clock" driven by high frequency currents.

FLEXIBLE POWER OPERATED AMPLIFIER.—W. H. Fortington. (*Rad. Engineering*, May, 1928, V. 8, pp. 30–33.)

A full description, with schematic diagram, of an amplifier suitable for use in addressing small audiences: it will handle a few watts of modulated energy and will deliver sufficient undistorted power to handle a quarter kW. modulator in a transmitter. Supply is entirely A.C., and the input conditions are flexible so as to allow coupling to all kinds of circuits. Ultra-high quality is not expected for the purposes in view, low cost and compactness being more considered.

AN ECONOMICAL 171 B-ELIMINATOR (An Economical power-mains adaptor for anode supply of Receivers).—J. R. Francis. (*Rad. Engineering*, May, 1928, V. 8, p. 35.)

The cost of the adaptor is reduced by getting rid of all choke-coils by the use of an electrolytic condenser; the unit thus consisting of the power transformer, a socket, the electrolytic condenser and two small resistances. The condenser utilises an aluminium oxide coating upon an aluminium sheet.

THE DEVELOPMENT OF THE HOT CATHODE X-RAY TUBE.—(*Journ. Sci. Instruments*, May, 1928, V. 5, pp. 170–172.)

A description of new types of tube whose containers are largely of metal; this development being made possible by improved methods of glass-to-metal sealing. As an illustration of the mechanical strength of such joints, it is mentioned that by using a corrugated cylinder of chromium iron to which glass insulating cylinders were sealed, the distance between two electrodes could be varied by several millimetres by applying mechanical pressure to the outside.

BESCHRIJVING VAN EEN TOONGENERATOR. . . . (Description of a L.F. generator).—B. F. J. Groeneveld. (*Physica*, May, 1928, pp. 157–164.)

The generator gives sinusoidal oscillations continuously variable from 25 to 25,000 kc. per sec. The form of condenser plate is shown, giving a logarithmic frequency scale.

CONSTRUCTION PRATIQUE ET UTILISATION DES SOUPAPES AU TANTALE (Practical Construction and Use of Tantalum Rectifiers).—Chardon. (*Rad. Revue*, June, 1928, V. 7, pp. 685–689.)

Since the recent Paris Fair, these rectifiers (ribbon of tantalum, lead sheet or wire, electrolyte of iron or nickel sulphate in sulphuric acid) have come into considerable favour.

AN EXPERIMENTAL INVESTIGATION OF SOME CHARACTERISTICS OF LOUD-SPEAKERS.—A. Kharkevitch. (*Teleg. i. Telef., b.p., Nichny-Novgorod*, June, 1928, V. 9, pp. 305–316.)

A COMPENSATED ELECTRON-TUBE VOLTMETER.—H. M. Turner. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 799–801.)

To eliminate the errors caused in valve-voltmeter readings by changes in the filament current, this method arranges that the grid bias changes with the filament current. Examples are given: in one, the resulting calibration is exact for filament current variations which would have caused 10.6 and 4 per cent. errors by the uncompensated method.

"MAINS" RADIO APPARATUS.—(*Nature*, 7th July, 1928, V. 122, p. 30.)

Regulations for the design and installation of this class of apparatus have now been issued by the I.E.E. with the approval of the Radio Manufacturers Association (*cf.* several recent "Abstracts" concerning the need for such regulations). The paragraph summarises about eight of these rules.

SOME FURTHER USES FOR THE NEON GRID-GLOW TUBE.—Wilkins and Friend. (*Journ. Opt. Soc. Am.*, May, 1928, V. 16, pp. 370–373.)

A two-electrode neon lamp ("Osglim") if connected in a suitable circuit will oscillate at regular intervals. The period of flashing is directly proportional to resistance *R* and capacity *C*; therefore the tube has been very usefully employed for the comparison of capacities or high resistances. A somewhat similar tube, but with a grid, has now been brought out under the name "Grid-Glow Tube" and two applications of this device are here described: for the registration of alpha rays, and as a sensitive voltmeter (1 volt through 15 megohms causing an easily measurable effect).

SOME NEW METHODS OF LINKING MECHANICAL AND ELECTRICAL VIBRATIONS.—W. H. Eccles and W. A. Leyshon. (*Nature*, 30th June, 1928, V. 121, p. 1042.)

A short notice of a paper read before the Physical Society on 25th May.

THE DESIGN OF THE FIELD MAGNET. FIELD STRENGTH AND LEAKAGE FLUX IN MOVING COIL LOUD SPEAKERS. A. P. Castellain. (*Wireless World*, 20th June, 1928, V. 22, pp. 665–668.)

THE PROBLEM OF RADIO SET POWER SUPPLY.—G. B. Crouse. (*Rad. Engineering*, May, 1928, V. 8, pp. 19–22, and June, pp. 42–44.)

Parts V. and VI. of a series, covering "Design Problems and the Application of Condensers and Inductance Coils to Socket Power Units" and "The Power Supply of the Future." In the first article the author details the eight points involved in a complete specification of condensers for such a filter circuit and proceeds to describe how the necessary values are to be determined. Inductances are then treated in a similar way. In the second article, the probable trend of development of power supply is considered. The author advocates the use of screen-grid valves with filaments in series, and gives diagrams of a 7-valve receiver on these lines.

DRY CELLS AND BATTERIES, U.S. GOVERNMENT MASTER SPECIFICATION FOR.—(*Bureau of Standards*, Washington, Circular No. 139.)

A full specification of construction, types, sizes, tests and required performance of cells of the salammoniac type with depolariser.

LABORATORY CURVE TRACER.—(*Journ. Sci. Instruments*, May, 1928, V. 5, pp. 167–170.)

A simple graphically recording instrument for recording the deflection of mirror instruments, without the elaboration entailed by photographic methods, and with greater accuracy than by readings at intervals entered in a note-book. The pen which records on a moving cylinder is provided with a cross-wire which is kept continually coincident with the mirror-image on the scale, by the manipulation of a controlling handle turning a leading-screw. Provision is made for more rapid movement, but from the description it would appear that some difficulty might be encountered in records involving large sudden changes.

MICROPHONE AMPLIFIERS AND TRANSFORMERS.—H. L. Kirke. (*E.W. & W.E.*, July, 1928, V. 5, pp. 361–370.)

L'EXTENSION DES APPLICATIONS DE L'OSCILLOGRAPHE CATHODIQUE DE DUFOUR (The extended application of the Dufour Cathode-ray Oscillograph).—K. Berger. (*Bull. de l'Assoc. Suisse des Elec.*, 7th May, 1928, V. 19, pp. 292–301.)

A description of an oscillograph so modified as to operate only in time for the phenomena to be recorded. It would seem to be based on the lines suggested by Gabor in 1927 (*cf.* also these Abstracts, under " Atmospherics," article by Norinder).

AMERICAN SOCIETY FOR TESTING MATERIALS: REPORT OF COMMITTEE D. 9 ON ELECTRICAL INSULATING MATERIALS.

Various revisions of standard methods, and new tentative methods, are proposed. It is noted that research at short wavelengths (15 to 30 m.) is being done by the collaboration of several firms and the Naval Research Laboratory.

ON THE " MISTUNING " OF WEIGHTED FORKS.—W. R. Miles. (*Journ. Sci. Instruments*, May, 1928, V. 5, pp. 152–154.)

Weighted tuning-forks are frequently used for their several advantages, *e.g.*, adjustability to different frequencies. In general, the weights cannot be adjusted with very great exactness, so that unequal adjustment of the two prongs is liable to occur. The author proves photographically that such inequality produces no error, since the two prongs always vibrate alike so far as rate is concerned, though the " slower " prong presents a lesser amplitude. Therefore in tuning a fork to a very specific rate (*e.g.*, for a phonic-motor chronograph) the fine adjustment may be done by only one weight.

STATIONS, DESIGN AND OPERATION.

SHORT WAVE MULTIPLEX SYSTEM OF RADIO COMMUNICATION.—Marconi - Mathieu. (*Nature*, 7th July, 1928, V. 122, p. 31.)

A paragraph describing experiments at the Bridgwater beam station, when music was sent from Montreal using the same apparatus and aerials as those through which two simultaneous Morse telegraph messages were being sent. The music was received at full strength, the quality was excellent, and there was no hint of Morse interference. It is also claimed that with the new apparatus the effects of " fading " are considerably diminished.

GENERAL PHYSICAL ARTICLES.

SUR L'EFFET VOLTA (on the " Volta " Effect of Contact Potential).—A. Cotton. (*Comptes Rendus*, 25th June, 1928, V. 186, pp. 1832–1833.)

The author had previously announced variations in the Volta Effect caused by heating in vacuo one of the two electrodes. In the present paper he describes how the effect of water vapour on several metals (including Iron, Nickel and Copper) is to make them more positive; on the precious metals no appreciable effect is noted. The author points out that in the usual measurements of Volta Effect, the metals contain a certain amount of water, so that very different values may be expected if the tests are repeated with anhydrous metals.

A NEW METHOD OF DETERMINING THE MOBILITY OF IONS OR ELECTRONS IN GASES.—Van de Graaff. (*Phil. Mag.*, July, 1928, V.6, pp. 210–217.)

Fizeau's rotating toothed wheel (used as a periodic shutter for determining the Velocity of Light) is here represented by an oscillating potential in combination with grids, producing a shutter effect for the ions or electrons whose velocity is to be measured.

ZUR ELEKTRONEN THEORIE DER METALLE NACH DER FERMISCHEN STATISTIK (The Electron Theory of Metals according to the Fermi Statistics).—A. Sommerfeld. (*Zeitsch. f. Phys.*, Nos. 1/2, V. 47, 1928, pp. 1–32 and 43–60.)

Part I. General, current and emission processes: Part II., thermo-electric, galvanometric and thermo-magnetic processes.

THE EMISSION OF SECONDARY ELECTRONS AND THE EXCITATION OF SOFT X-RAYS.—O. W. Richardson. (*Proc. Royal Society*, July 1928, No. A, 783, pp. 531–542.)

The particular point dealt with here is the origin of that part of the secondary electron emission which does not result from reflection.

On the Kinetic Method in the new Statistics and its Application in the Electron Theory of Conductivity.—L. W. Nordheim. (*Proc. Royal Society*, July, 1928, No. A. 783, pp. 689–698.)

The dynamical theory of gases, developed by Maxwell and Boltzmann, is here successfully applied to the electron theory of conductivity.

Experiments on the Diffraction of Cathode Rays. G. P. Thomson. (*Proc. Royal Society*, July, 1928, No. A. 783, pp. 651–663.)

A continuation of the author's work on the diffraction patterns produced on a photographic plate by a beam of cathode rays passing normally through a very thin film of metal. These are now shown to be in complete agreement with those which can be predicted on the de Broglie wave theory, the atoms of the metal crystals being the diffracting system. The velocity of the diffracted electrons differs by less than 1 per cent. from that of the main beam. The electrons must be accompanied by a train of not less than about 50 waves.

The Piezo-electric Resonator and its Equivalent Network.—K. S. Van Dyke. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 742–764.)

The paper deals first with the piezo-electric effects as first known, the quantitative results obtained by the Curies fifty years ago, and the complete theory worked out by Voigt; it then shows how the introduction of resonance (about 1919) altered the whole importance of the phenomenon, magnifying the effects several thousandfold The author shows that the functions of the quartz as dielectric and as vibrator are separable and replaceable by a condenser in parallel with an electric resonator, *i.e.*, a series chain of inductance, resistance, and capacity. Illustrative values for the elements of the network are given: for a plate of a size commonly used in oscillators, $L = 0.33$ henry, $R =$ about 5,500 ohms, $C = 0.065\ \mu\mu F.$, $C_1 = 1.0\ \mu\mu F.$ (C_1 being the parallel condenser). The paper concludes with a description of experiments, with a cathode-ray oscillograph, on the nature of the variations in the crystal impedance as the frequency is varied through resonance.

Evidence for the Continuous Creation of the Common Elements out of Positive and Negative Electrons.—Millikan and Cameron. (*Proc. Nat. Acad. Sciences*, June, 1928, V. 14, pp. 445–450.)

A full and authoritative account of the author's latest work on cosmic rays and the conclusions drawn from it. It is stated that the results cannot be explained by a step-by-step process of building up, but only by creation in a single act. The tone of the authors is much more confident than in the paper abstracted in the August number: they conclude with the following sentence: "This whole work constituted, then, very powerful evidence that the sort of creative, or atom-building processes discussed above, are continually going on all about us, possibly also even on the earth, and that each such event is broadcast through the heavens in the form of the appropriate cosmic ray."

Radiation and Relativity.—G. Y. Rainich. (*Proc. Nat. Acad. Sciences*, June, 1928, V. 14, pp. 484–488.)

The first part of a paper in which the author proposes to study systematically from the relativity point of view a particle moving with the velocity of light, following the methods by which a material particle is studied.

The Negative Absorption of Radiation.—Raman and Krishnan. (*Nature*, 7th July, 1928, V. 122, pp. 12–13.)

Earlier work of the writers showed that when a liquid (*e.g.*, benzene) is irradiated by monochromatic light, the radiation scattered by the molecules contains several spectral lines of modified frequencies, each equal to the incident frequency less one of the characteristic infra-red frequencies of the molecule; so that the process of modified scattering involves the absorption of radiation by the molecule. They now find that in addition to these modified (longer) wavelengths there are present two modified *shorter* wavelengths (less bright) whose frequencies each exceed that of the existing wave by one of the infra-red frequencies of the molecule. The presence of these lines proves simultaneously the existence in the liquid of molecules at levels of energy correspondingly higher than the normal, and the fact that the incident radiation induces a return to a lower state of energy; in other words, that there is a negative absorption of the radiation, a hitherto unproved phenomenon characteristic of Einstein's derivation of the Planck radiation formula and also figuring prominently in the Kramers-Heisenberg theory of dispersion.

Theory of the Kerr and Faraday Effects in Gases. Part II. Quadratic Effects.—R. de L. Kronig. (*Zeitschr. f. Phys.*, V. 47 No. 9–10, 1928, pp. 702–711.)

The Waves of an Electron.—G. P. Thomson. (*Engineering*, 20th July, 1928, V. 126, pp. 79–80.)

An account of the paper read before the Royal Institution on June 8th.

The Reflection of X-Rays from Glass and Quartz.—Laby, Shearer and Bingham. (*Nature*, 21st July, 1928, V. 122, pp. 96–97.)

It is well known from the work of Compton and others that X-rays can be reflected at glancing angles up to about 40 mts., and Holweck claims to have observed reflection at 16.2 deg. The writers have obtained reflection of X-rays of about 50 A.U. from glass and quartz up to glancing angles of 45 deg. The ratio of intensity of incident to reflected beam is about 2 to 1 up to 35 deg.: above that angle the intensity of the reflected ray decreases. It appears that the reflected radiation is X-radiation, and not cathode rays or ultra-violet. The results do not seem to be reconcilable with the Lorentz dispersion formula. If these preliminary observations have been correctly interpreted, X-rays can be reflected from spherical surfaces and brought to a focus.

STOSSSPANNUNG UND DURCHSCHLAG BEI GASEN (Shock-voltage and Discharge through Gases)—W. Rogowski. (*Archiv. f. Elektrotech*, 11th May, 1928, V. 20, pp. 99–106), and BREAKDOWN OF SPARK GAPS.—J. Slepian. (*Elec. World*, 14th April, 1928, V. 91, pp. 761–765.)

Both authors point out the failure of the classical Townsend theory under conditions of very transitory applications of potential, and propound their ideas as to how that theory should be modified. The second writer formulates a theory which gives much shorter times for the breakdown process, depending on thermal ionisation; at a gradient just sufficient for breakdown, an electron starting from the cathode will cause thermal ionisation to appear near the anode. With larger voltages, this ionisation sets in much closer to the cathode, the positive ions at the cathode-end of the thermally-ionised trail need to move a shorter distance and are driven by a stronger field, so that the time is greatly reduced by a slight over-voltage.

STATISTICAL EXPERIMENTS ON THE MOTION OF ELECTRONS IN GASES.—R. d'E. Atkinson. (*Proc. Royal Soc.*, 1st June, 1928, V. 119, Series A, pp. 335–348.)

Prof. Townsend's Oxford experiments have been considered by him to show results irreconcilable with the theories generally accepted. The object of the present paper is to show that this is not really the case: it suggests that the apparent contradiction depends largely on the fact that the term-systems of the principal gases studied contain metastable states among their lowest excited levels —a fact relatively unimportant in the critical-potential work, but effecting an enormous and apparently quite unsuspected disturbance when statistical high-pressure methods are employed, as is always the case in the work of Townsend.

UNTERSUCHUNGEN UBER DEN MECHANISMUS DES LICHTBOGENS (Investigation of the Mechanism of the Electric Arc Discharge).—R. Seeliger. (*E.T.Z.*, 7th June, 1928, V. 49, pp. 853–857, and "Discussion," pp. 880–881.)

INFLUENCE OF WEAK MAGNETIC FIELDS ON THE DEGREE OF POLARISATION OF THE LIGHT EMITTED BY HYDROGEN CANAL RAYS.—v. Traubenberg. (*Phys. Zeit.*, 1st December, 1927, pp. 856–857.)

PHÉNOMÈNES D'IONISATION DES GAZ (Phenomena of ionisation of gases).—— Abadie. (*Génie Civil*, 12th May, 1928, V. 92, p. 472.)

Summary of a paper read before the Société Française des Électriciens, dealing with luminescent vacuum tubes in which the residual gas may be an ordinary or a rare gas. The author points out that such a tube supplied with alternating current does not absorb the whole of the current; it produces watt-less current and plays the part of a self-inductance; therefore, instead of supplying high-tension A.C. it is better to use high frequency, these tubes having a natural frequency corresponding to wavelengths between 300 and 400 m. The efficiency of a tube excited at H.F. is considerably increased. Its life is limited by the absorption of the residual gas, and this the author overcomes by regenerating the atmosphere by the dissociation of a salt; as a result, he has obtained a tube lasting more than 12,000 hours. He has also succeeded in reducing the cathode drop (usually 150–300 volts) to 12 volts.

THE ELEMENTS OF WAVE MECHANICS.—L. M, Milne-Thomson. (*Nature*, 2nd June, 1928. V. 121, pp. 885–886.)

An article based on Prof. Schrödinger's lectures at the Royal Institution last March.

REPORT OF WORK OF BARTOL (RESEARCH) FOUNDATION.—W. F. G. Swann. (*Journ. Franklin, Inst.*, June, 1928, V. 205, pp. 767–829.)

Continued from August " Abstracts."

(8) The variation of dielectric constant of a solution with concentration of the dissolved salt.

(9) The nature of the processes occurring in certain electric arcs. (Incidentally, a photo-electric cell is mentioned which will detect the light of a match at one-third of a mile).

(10) The reflection of hydrogen atoms from crystals. Dr. Johnson has obtained reflection of a beam of atomic hydrogen characterised by equality of angles of incidence and reflection.

(11) A device for obtaining high potentials (it is hoped, of the order of a million volts) based on the " water-dropper " idea, but in a vacuum, and with the water replaced by a steel ball.

(12) The variation of residual ionisation of a gas with pressure as a function of the altitude.

MISCELLANEOUS.

ANALOGY BETWEEN THE CRYSTAL DETECTOR AND A VACUUM TUBE.—W. Ogawa. (*Phil. Mag.*, July, 1928, V. 6, pp. 175–178.)

According to the writer's theory, the rectification by a crystal detector is brought about by the difference of electrons emitted from each electrode. He finds experimental verification in a test made with a crystal detector couple (galena and copper rod) sealed in a glass tube with a small space between metal and crystal. On exhausting the tube and applying A.C. potential of the right value, a glow discharge starts up and rectified current results in the same direction as in the corresponding contact rectifier.

EIN EINFACHES VERFAHREN ZUM MAGNETISIEREN VON PERMANENTEN MAGNETEN (A simple method of magnetising permanent magnets). —E. Schulze. (*E.T.Z.*, 28th June, 1928, V. 49, pp. 969–974 and 993–994.)

This patented method uses the large surge in the almost short-circuited single turn secondary of a transformer excited by D.C., at make or break of the primary current. With a transformer rated at less than 12 kVA., surges of 10,000 A. and more can be obtained.

ÜBER DEN EINFLUSS DER NICHTLINEAREN EISENVERZERRUNGEN AUF DIE GÜTE UND VERSTÄNDLICHKEIT EINES TELEPHONIC-ÜBERTRAGUNGSSYSTEMES (The influence of non-linear iron-distortion on the quality and intelligibility of telephone transmission).—G. V. Békésy. (*E.N.T.*, June, 1928, V. 5, pp. 231–246.)

This paper includes a method for measuring the strength of the overtones of a loud-speaker. The apparatus includes a Quincke interference-tube, and each overtone is adjusted in turn to be as loud as the fundamental: the amount of adjustment required to produce this equality gives a measure of the overtone.

ZUR ANWENDUNG DER KURZEN WELLEN IM VERKEHR MIT FLUGZEUGEN: VERSUCHE ZWISCHEN BERLIN UND MADRID (The use of short waves for communication with Aircraft: Tests between Berlin and Madrid).—Krüger and Plendl. (*Zeitschr. f. Hochf. Tech.*, June, 1928, V. 31, pp. 169–176.)

Transmission was from ground sets at Berlin and from aeroplane sets in the neighbourhood; reception was at Madrid (distance about 2,000 kms.). Previous tests over Germany had shown that for distances up to 1,000 kms. the wave-band 40–50 m. was particularly effective, a power in the aerial of only 1 watt giving good telegraphic communication particularly at night. The present longer range tests showed that the 46 m. wave with 2 watts in the aerial gave moderate communication up to 1,400 kms., but would not reach the 2,000 kms. range by day even with power increased 150 times. On the other hand, a 30 m. wave gave "news" communication with either 0.5 (aeroplane) or 300 watts (ground) in the aerial. The best waves for day and night were found to be 27–30 m., while 16–19 m. was only slightly inferior.

GEOPHYSICAL METHODS OF PROSPECTING.—Eve and Keys. (*U.S. Bureau of Mines*, Tech. Paper 420, reviewed in *Nature*, 7th July, 1928.)

The methods described are the magnetic, gravitational, electric and seismic; other methods, which have as yet been "inadequately tested," are only enumerated.

DEMONSTRATION OF A PORTABLE ELECTRIC HARMONIC ANALYSER, SHOWING THE MEASUREMENT OF HARMONICS IN VOLTAGE AND CURRENT WAVES.—R. T. Coe. (*Proc. Phys. Soc.*, 15th June, 1928, V. 40, p. 228.)

The determination of each harmonic only takes a few minutes; the amplitudes of small harmonics in voltage waves are found correct to at least 1-20th of 1 per cent. of the fundamental. The method embodies the mathematical principle of obtaining the *n*th harmonic by multiplying by Sin *npt* and integrating over a complete period.

TELEVISION BY CATHODE RAYS.—A. A. Campbell Swinton. (*Modern Wireless*, June, 1928.)

The writer carried out experiments in 1903–1904, and in 1908 published what is believed to be the first published suggestion of the use of cathode rays for television, both at the transmitter and at the receiver. Since then numerous patents have been taken out. Recent demonstrations of television have depended on mechanically moving devices, and the writer urges the abandonment of such clumsy methods and the development of methods in which the only moving parts are imponderable electrons.

FOCUSSING ELECTRONS REFLECTED OR EMITTED AT EQUAL ANGLES FROM A PLANE SURFACE.—D. A. Wells. (*Journ. Opt. Soc. Am.*, May, 1928, V. 16, pp. 355–356.)

ÉMISSION ET RÉCEPTION PAR UN RÉCEPTEUR À SUPER-RÉACTION (Transmission and reception by a super-regenerative receiver).—G. Beauvais. (*l'Onde Élect.*, May, 1928, V. 7, pp. 206–209.)

The writer obtains inter-communication by making use of the fact that when two stations are using super-regenerative receivers on very short waves, they often hear each other. The necessary wave-change at each end is accomplished by short-circuiting a loop of wire coupled to the self-inductance of the oscillating circuit, when switching over from transmission to reception.

CRUISE VII OF THE "CARNEGIE," 1928–1931.—(*Nature*, 2nd June, 1928, V. 121, pp. 871–873.)

A programme of the new cruise, which should amount to 110,000 miles. Among the great mass of work to be done may be mentioned: determinations of changes in the values of the atmospheric electric elements with geographic position (a photographic recorder to record continuously variations in atmospheric potential gradient; ionic-content apparatus); measurement of the penetrating radiation and the radio-active content; dust-count observations; measurement of marine electric currents; investigation of variations in transmitting and receiving conditions, skip-distance and signal-intensity (short wave radio signals).

DIE RADIOTECHNIK AUF DER LEIPZIGER FRÜHJAHRSMESSE, 1928 (Radio technics at the Leipsic Spring Fair, 1928).—(*E.T.Z.*, 17th May, 1928, p. 749.)

Improvements in detail, rather than actual novelties, are prominent. Multiple valves, combining several systems in one valve, have won a good place. In the design of adaptors to the public mains supply, elimination of noises is attended to and special attention is given to the use of filters in the attempt to make distant reception faultless; apparently complete success has not yet been attained. Quality of reproduction in loud speakers shows improvement; a particular make is named as giving perfect reproduction of the very deepest bass without detriment to the high frequencies.

One example of electric reproducers for gramophone is highly commended. Coil units covering 180–5,000 m. in three stages which are controlled by a barrel-switch mounted on the unit, and various forms of indoor aerial, are mentioned; a thermo-electric battery to replace the filament-accumulator (requiring about 100 watts for a supply of 0.4 amp. at 2 v.) is described, also a practical accumulator-tester composed of a glow-lamp and two resistances so mounted that one of these takes the full working current while the other combines with the lamp to form a sensitive voltmeter.

DIFFERENTIAL INTENSITY SENSIBILITY OF THE EAR FOR PURE TONES.—R. R. Riesz. (*Phys. Review*, May, 1928, V. 31, pp. 867–875.)

The ratio (Minimum perceptible increment in sound intensity): (Total Intensity) was measured as a function of frequency and intensity, over practically the entire range of both variables for which the ear is capable of sensation. The method is described and results are given in curves. The ratio is a minimum at about 2,500 p.s. frequency, corresponding to the region of greatest absolute sensitivity of the ear. At 1,300 p.s., it is calculated that the ear can distinguish the maximum number (370) of tones as being of different intensity.

UN NOUVEAU SYSTÈME DE TÉLÉVISION ET DE TÉLÉCINEMATOGRAPHIE (A new system of Television and Telekinematography).—L. Thurm. (*Q.S.T. Franç.*, July, 1928, pp. 55–57.)

The system described, which has already been demonstrated, differs from the usual systems in that transmission does not take place synchronously with the scene-events, the currents derived from the exploration of the latter being temporarily stored up in "magnetic spirals." This is done by passing the current derived from each photo-electric element of the exploring "retina," after amplification, through an electromagnet before which passes a steel band; each retina-element exploring only a portion of the scene and each having its electromagnet and band. Thus the rate of the actual wireless transmission is rendered independent of the rate at which the scene itself moves.

Practical details are promised in the next instalment.

PERSONAL AND IMPERSONAL STYLES IN SCIENTIFIC COMMUNICATIONS.—N. R. Campbell. (*Nature*, 30th June, 1928, V. 121, p. 1021.)

A protest against the present "stylistic fad" encouraged by some editors against the use of the first person in scientific writings: not as part of a more general crusade against the egotism which leads to squabbles over priority and the assignment of credit, but merely as an isolated, clumsy, and artificial fashion. The writer suggests that writers should learn from Faraday, Rayleigh, Huxley and many others how to say "I" freely, naturally, with elegance and with dignity.

AT THE SCIENCE MUSEUM: SOME RECENT ADDITIONS TO THE RADIO SECTION.—R. P. G. Denman. (*Wireless World*, 11th July, 1928, V. 23, pp. 49–53.)

Among other interesting items may be mentioned the three dimensional valve characteristic models for various types of valves.

LE GRAND ÉLECTRO-AIMANT DE L'ACADÉMIE DES SCIENCES.—A. Cotton. (*Comptes Rendus*, 9th July, 1928, V. 187, pp. 77–89.)

This magnet has just been completed. It is explained that whereas Kapitza (*cf.* August Abstracts) has attained fields of hundreds of thousands of gauss, these fields are very transient and very small in volume. With the French magnet, a steady field, between pole-pieces 4 cm. in diameter and 2 cm. apart, has been obtained up to 46,400 gauss. More powerful fields of smaller volume are in process of being measured.

EUROPEAN PROGRESS IN TELEVISION.—W. J. Brittain. (*Science Progress*, January, 1928, V. 22, pp. 493–494.)

A short but comprehensive survey of the various different systems.

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPRECOJ DE CIRKVITOJ.

INTER-ELEKTRODAJ KAPACITOJ KAJ REZISTECA AMPLIFADO.—L. Hartshorn.

Oni atentigas, ke la kutima analizo de rezisteca-kapacita amplifado supozas, ke la ŝunta efekto de elektrodaj kapacitoj ĉe la diversaj rezistecoj estas malgranda, sed la aŭtoro asertas, ke ĉi tiu efektiva kapacito povas facile esti 100$\mu\mu$F. aŭ pli.

Li poste diskutas enmetan impedancon, admitancon, kaj kapaciton, rilate al la ekvivalenta retaĵo por unu aŭ por du ŝtupoj, kaj montras ke, kaŭze de la tuta amplifado, la efektiva krada kapacito en unu ekzemplo estas 110$\mu\mu$F. Ponta metodo estas priskribita kaj ilustrita por la mezurado de enmeta admitanco kaj kapacito, tabeloj donantaj eksperimentajn rezultojn por enmeta kapacito kaj enmeta konduktanco.

La aplikado de ĉi tio al la rezisteca-kapacita amplifikatoro estas poste diskutita sub la rubrikoj (*a*) Kradanoda kapacita efekto ; (*b*) Anodimpedanca termino ; (*c*) Kupla termino, k.t.p. La efekto de mem-kapacito en la kutima formo de anoda rezisteco estas ankaŭ diskutita.

Tre utila fina resumo estas verkita laŭ la konsideradoj de la antaŭiranta teksto.

LA RESONANCAJ KURVOJ DE KUPLITAJ CIRKVITOJ.—Prof. E. Mallett.

La aŭtoro unue aludas al antaŭaj artikoloj (*E.W. & W.E.*, Feb.–Marto, 1927a) pri l'uzado de vektoraj metodoj por obteni la resonancajn kurvojn de unuoblaj oscilaj cirkvitoj, post kio li paŝas al simila traktado pri kuplitaj cirkvitoj, kiam la frekvenco estas variigita. La ekzemplo de du agorditaj cirkvitoj kuplitaj per komuna indukteco estas unue konsiderita, la fundamentaj esprimoj estante donitaj kun vektora konstruado kaj la rezultanta kurvo por Z kaj i_2. La rezonado estas etendita al aliaj metodoj de kuplado, ekzemple, iu formo de komuna impedanco, kaj ankaŭ al cirkvitoj iomete malagorditaj. Etendado al tri (indukte kuplitaj) cirkvitoj estas ankaŭ donita, kaj la etendado al kvar aŭ pli da cirkvitoj mallonge indikita.

RICEVADO.

KVALITO KONTRAŬ SELEKTIVECO JE MALPROKSIMA BRODKASTA RICEVADO.

Redakcia artikolo, super la ĉefliteroj de Prof. Howe. Oni aludas al lastatempa prelego ĉe la Institucio de Radio-Inĝenieroj, de Vreeland, kaj al la efektiva bezono por rektangula responda kurvo, tiel ke ĉiuj frekvencoj, ekzemple, 10 k.c. sur iu flanko de la portondo povas esti egale ricevita. Metodoj por larĝigi la respondan kurvon estas mallonge diskutita, ĉi tiuj estante amortizado, frekvenca interspacado de kaskadaj ŝtupoj, kaj la uzado de du agorditaj cirkvitoj rigide kuplitaj por doni kurvon kun du ĝiboj.

La teoria esplorado pri la relativaj meritoj de ĉi tiuj metodoj estas sugestita kiel interesa problemo.

MEZUROJ KAJ NORMOJ.

LA MEZURADO DE MALGRANDAJ VARIEBLAJ KAPACITOJ JE RADIO-FREKVENCOJ.—W. H. F. Griffiths.

La aŭtoro unue atentigas, ke malgranda aerkondensatoro ne estas normigebla, krom se ĝiaj konduktoroj kaj skrenaj kondiĉoj (uzotaj post normigado) estas konataj kaj starigataj dum normigado. La malfacilaĵoj de tiaj mezuroj estas diskutitaj detale kaj bone ilustritaj per skizoj. La aŭtoro sugestas, ke estas pliigo de kapacito laŭ skalo, kio estas plej grava dum praktiko kaj, ke oni povas aranĝi, ke ĉi tiu metodo de normigado certigu, ke nur la linia porcio de l'skalo estas uzata. Li poste komencas diskuti precizan metodon de ĉi tiu " dekliva kapacita " normigado.

La metodo estas priskribita multdetale, kun tipaj rezultaj tabeloj, kaj notoj estas donitaj pri eblaj eraroj, utilaj proksimumaĵoj, mezurado de falsa nulo, la korekta determino de mem-kapacito en la cirkvito, k.t.p.

HELPA APARATO.

MIKROFONAJ AMPLIFIKATOROJ KAJ TRANSFORMATOROJ.—H. L. Kirke.

Findaŭrigita el lasta numero.

La nuna parto konsideras la rezistec-kapacitan kaj ŝok-kapacitan ŝtupojn. La dimensioj de intervalvaj kondensatoroj estas unue diskutitaj, kaj la reakcio kaŭze de interelektroda kapacito. La efekto de Kontinua Kurento ĉe transformatoroj estas poste pritraktita, kaj la ŝok-kapacita kuplo al transformatora primario estas diskutita. Oni opinias, ke ŝoka kuplo al la elmeta transformatoro estas avantaĝa. Rezistanca kaj ŝoka kuplo estas poste diskutita kvante, kaj ĝenerala komparo donita pri transformatora, ŝoka, kaj rezistanca kuplo. Por bona entuta kurvo per multŝtupa amplifikatoro, rezistanca kuplo estas la sola formo, kiu estas uzebla ĉe mikrofonaj amplifikatoroj por brodkastaj celoj.

La aŭtoro poste diskutas distordadon sub la rubrikoj de l'Amplitud-Pligrandiga Karakterizo kaj de Fera Distordado. Laste, li traktas pri la Pligrandigo bezonita ĉe Amplifikatoroj, faktoro de sendanĝereco, mekanika desegnado de amplifikatoroj (aparte por eksterdoma aŭ teatra brodkastado), kaj la skalo de volumen-kontrolo necesa.

DIVERSAĴOJ.

RESUMOJ KAJ ALUDOJ.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

LA OPERATORO " HEAVISIDE " A KAJ LA OPERATORA KALKULUSO.—W. A. Barclay.

Ĉi tiu artikolo grandparte naskiĝis pro la lastatempa kontribuaĵo de S-ro J. A. Ratcliffe (*E.W. & W.E.*, Majo, 1928a), kaj la Redakcia kritiko kiu estis donita.

La nuna aŭtoro diskutas simbolajn sistemojn kaj paŝas al la Operatoro Heaviside'a $D = \frac{d}{dt}$. Li poste traktas pri la Operatora Ekvacio, kondukante al la Impedanca Operatoro, kun ekzemploj koncerne seriaj kaj paralelaj L.C.R. (Indukteco, Kapacito, & Rezisteco) cirkvitoj. La agadmaniero uzi la Operatoron estas mallonge resumita, kaj la aŭtoro finas per kritiko de la Diferenciala Operatoro, kaj de la Heaviside'a Operatora Kalkuluso.

Some Recent Patents.

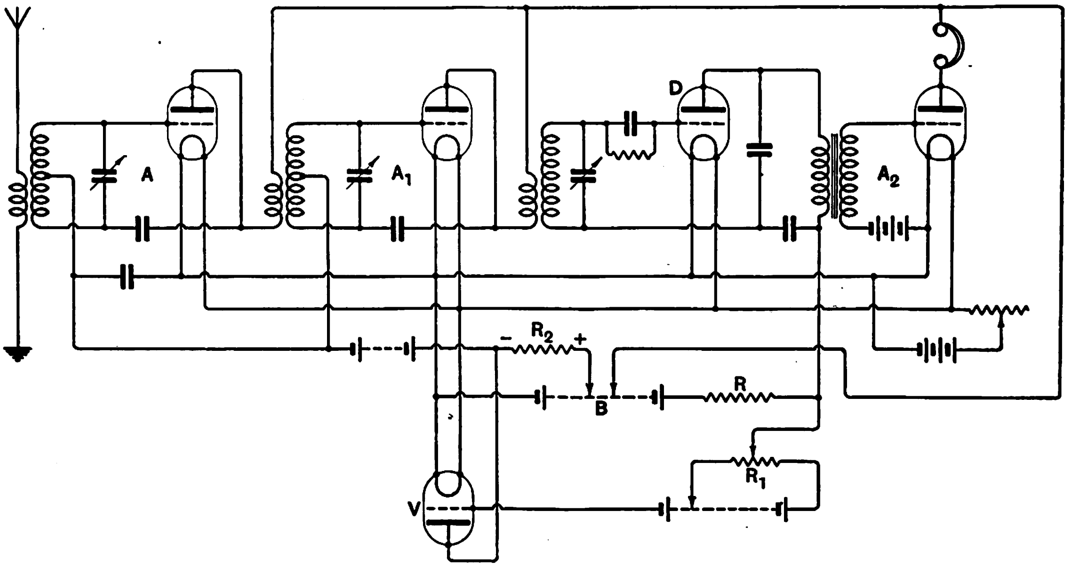
The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

MINIMISING FADING EFFECTS.

(*Convention date* (*U.S.A.*), *3rd January,* 1927. *No.* 283,120.)

In order to ensure a uniform overall strength of reception, irrespective of fluctuations in the intervening medium due to atmospheric conditions, means are provided for automatically adjusting the grid-bias of the receiving valves in accordance with the volume of the rectified signals. The Figure shows two neutralised high-frequency amplifiers, A, A_1, feeding a detector valve D and a subsequent stage A_2 of low-frequency amplification.

The rectified current from the detector D flows through a resistance R, which regulates the effective voltage across the grid and filament of an auxiliary amplifying valve V. A resistance R_2 in the plate circuit of the latter valve is, in turn, included in the input circuit of the first amplifier A and serves to regulate its operative grid-bias. When the signals rise above normal strength, the voltage across the resistance R falls, and this allows the battery B to throw the grid of the amplifier V more positive. The resulting increase in plate current alters the potential drop across the resistance R_2 in the sense that the end of the resistance connected to the grid of the first amplifier becomes more negative, thus tending to cut down the initial amplification. Should the received signals be too weak, the grid of the first amplifier is thrown more positive.

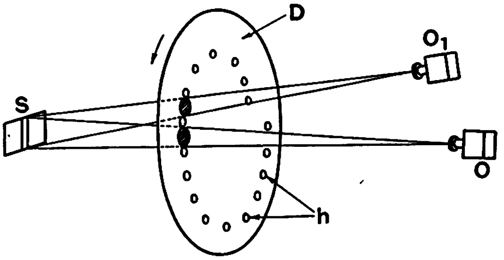


Patent issued to British Thomson-Houston Co., Ltd.

TELEVISION APPARATUS.

(*Application date,* 30*th November,* 1926. *No.* 291121.)

Relates to a viewing-screen for the reception of moving-picture effects in which the surface is phosphorescent in character, *i.e.*, in which the semi-permanent image persists for a certain length of time depending upon the nature of the surface coating, as distinct from a fluorescent screen where the luminescence ceases as soon as the activating light is cut off.



In order to prevent undue persistence in a screen of phosphorescent material, such as calcium sulphide, means are provided for obliterating each image by projecting over the surface a ray of light of longer wavelength than that emitted by the screen. As shown in the Figure a rotating disc D having a spirally-arranged series of holes h traverses the phosphorescent screen S with light from a source O, which is controlled by the incoming "television" signals so as to build up a visual image on the screen.

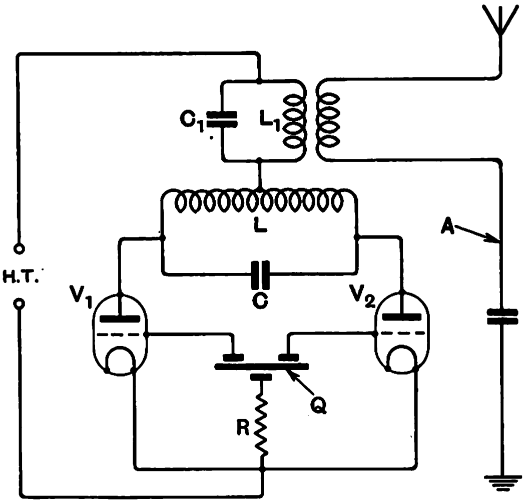
An obliterating ray, say of infra-red wavlength, derived from a second source O_1 after passing through a suitable filter, is swept over the screen by the same disc *D*, either immediately before or immediately after a new image has been projected from the source *O*. The method is stated to be also applicable to an arrangement where the phosphorescent screen is replaced by a bank of lamps fitted with shutters, the opening of which is controlled by the activating light-ray and the shutting by the infra-red ray.

Patent issued to Television, Ltd., and J. L. Baird.

FREQUENCY-DOUBLING.

(*Convention date* (*Germany*), 13*th January*, 1927. *No.* 283549.)

In order to generate short-wave energy, two valves V_1, V_2 are fed in parallel through a circuit *L*, *C*, the high-tension supply being tapped to a potential node along the coil *L*. The grid-filament connection comprises a piezo-electric oscillator *Q* provided with split electrodes to ensure a symmetrical connection to the common leak resistance *R*. Oscillations corresponding to the fundamental crystal frequency are thereby produced in the resonant circuit *L C*.



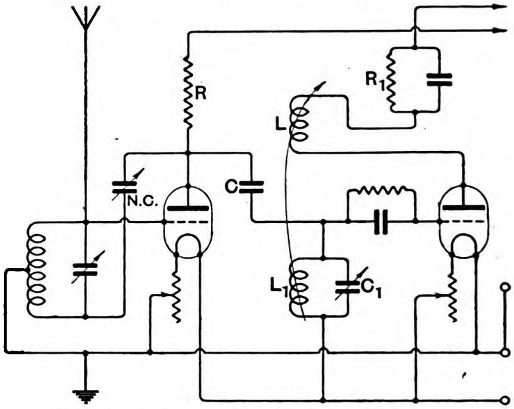
During each half-period of oscillation, energy passes first through one valve V_1 and then through the other V_2, producing in each complete oscillation two current impulses, which is equivalent to an alternating current of double the main oscillation frequency. The latter frequency is absorbed by the loop circuit L_1, C_1 and is then fed to the transmitting aerial *A*. In the limiting case, the tuned circuit *L C* is replaced by a plain connecting wire which co-operates with the interelectrode capacities of the valves to form a resonant circuit of very short wavelength. The H.T. supply is taken to the centre of the plain wire, which is a potential node, and the doubled frequency is tapped off to the aerial by a direct metallic coupling at another point of zero potential variation.

Patent issued to C. Lorenz Co., Ltd.

REACTIVE RESISTANCE-COUPLINGS.

(*Application date*, 15*th March*, 1927. *No.* 291.894.)

The ordinary resistance-capacity coupled amplifier tends to fall off in efficiency on the shorter wavelengths owing to the increasing shunt effect of the internal valve capacities. Again, special provision is necessary in order to utilise reaction to a beneficial extent. The figure shows a circuit designed to operate efficiently on the higher frequencies, with reaction, the first valve being arranged to protect the aerial from any feed-back sufficient to cause reradiation.



The coupling condenser *C* between the resistance *R* in the plate of the first valve and the tuned input L_1, C_1 in the grid of the second is chosen so that it has a comparatively low impedance compared with *R* and with the internal plate-filament capacity of the first valve. When *R* is 100,000 ohms a suitable value for *C* would be 0.01 mfd. By tuning the grid condenser C_1, the output and input impedances can be brought to a maximum and the reactive coupling correspondingly controlled. In the second valve an inductive winding *L* is coupled to the input coil L_1, the value of the resistance R_1 being less than that of *R* in order to allow an appreciable current to flow in the plate circuit of that valve. A neutralising condenser *NC* prevents the aerial from being energised through the first valve.

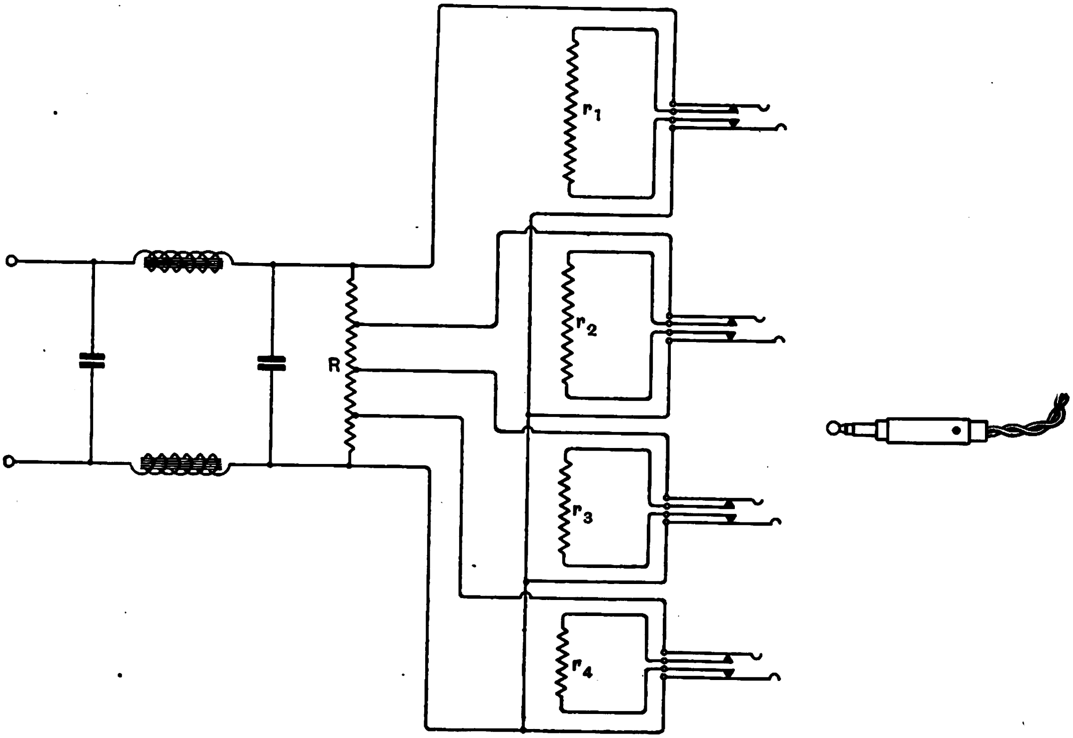
Patent issued to H. J. Stenning and the Edison Swan Electric Co., Ltd.

VOLTAGE REGULATION IN H.T. ELIMINATORS.

(*Application date*, 27*th January*, 1927. *No.* 289,530.)

One drawback to the use of H.T. eliminators lies in the difficulty of maintaining a constant voltage-drop across the shunt resistance *R* from which tappings to the various plate circuits are taken. Any alteration in the output current, caused by changing the number of valves in circuit, or otherwise, affects the terminal voltage and so gives rise to bad regulation.

In order to overcome this defect separate compensating resistances r_1, r_4 are arranged to be automatically bridged across any section of the potentiometer R not actually in use. Each resistance should be approximately equal in value to the external circuit which would under normal circumstances be connected across the section in question. In this way the current-flow across each section of the potentiometer R is kept substantially constant, so that the voltage of each tapping point remains steady no matter how many valves are switched in or out of circuit.



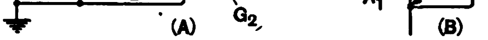
Patent issued to The British Thomson-Houston Co., Ltd.

MULTI-STAGE VALVES.

(*Application date*, 11*th March*, 1927. *No.* 292,218.)

Relates to valves of the type on which several stages of amplification are housed inside the same bulb. As shown in Figs. A and B, a central anode A_1 is surrounded first by a grid G_1, then by a filament K, next by a second grid G_2, and finally by an outer cylindrical anode A_2. The relative spacing of the various electrodes is such that the effect of the grid G_1 on the electron stream flowing between K and A_1 is greater than the effect of the grid G_2 on the stream between K and A_2.

When connected up in the manner shown in Fig. A, the overall amplification is stated to be greater than that obtainable from two separate valve stages coupled in series. The input circuit LC is connected across the grid G_2 and the negative end of the filament K. The central anode A_1 is connected through a 5-megohm resistance R to a high-tension supply of about 30 volts, and also through a blocking-condenser C_1 to the outer grid G_2. The telephones are inserted between the outer anode A_2 and the high tension. The amplified voltage variations on the central anode are transferred through the condenser C_1 to the outer anode A_2, the combined action of the two grids and anodes on the common electron stream giving rise to a reaction effect which increases the magnification factor.

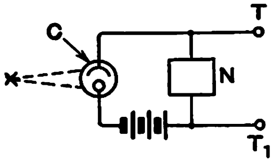


Patent issued to A. H. Midgley.

PHOTO-ELECTRIC RELAYS.

(*Application date*, 14*th February*, 1927. *No.* 290367.)

If light falls suddenly upon the active electrode of a photo-electric cell, the resulting current does not rise instantaneously to its maximum value, but is subject to a lag analogous to that observed in the case of selenium though smaller in magnitude and more complex in character. The lag is due partly to the time necessary for ionisation to set in between the cell electrodes, and partly to the fact that the internal resistance is, in effect, shunted by the inherent capacity of the cell itself including the external leads, and that a time interval occurs before this capacity is charged up to a steady potential.



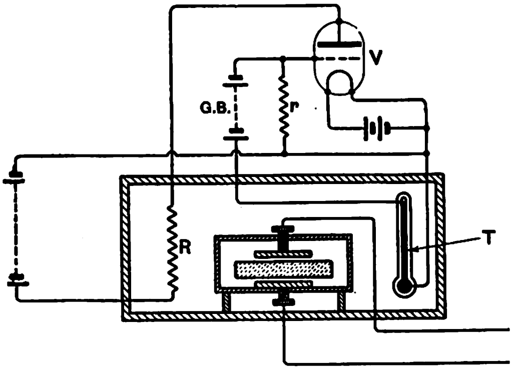
In order to correct for any distortion due to this sluggishness in high-speed picture telegraphy, or in television, the photo-electric cell *C* is inserted in series with an impedance network *N* which "matches" the cell impedance over the range of working frequencies. The output *T*, T_1 is tapped off across the impedance *N* so that the system constitutes a balanced wheatstone bridge. Variations in the input are accordingly repeated across the conjugate output points independently of any time-lag effect in the respective arms of the bridge.

Patent issued to G. M. Wright.

FREQUENCY-STABILISING DEVICES.

(*Convention date* (*U.S.A.*), 15*th January*, 1927. *No.* 283596.)

It has been found that the fundamental oscillation frequency of a piezo-electric crystal varies with temperature as much as 30 cycles per second for every degree centigrade when set to a normal frequency of one million cycles per second. In order to remove this source of fluctuation a master-control crystal is housed inside a suitable covering which is maintained at a uniform temperature by the device shown in the figure.



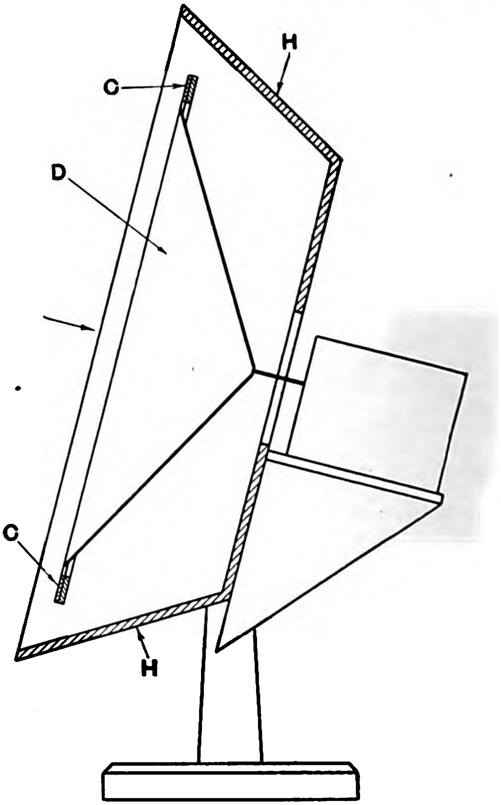
The plate circuit of a valve *V* contains a heating-resistance *R* located inside the crystal casing, whilst the grid circuit comprises a thermometer *T* so arranged that when the temperature falls below a given point, a paralysing negative potential from the battery *GB* is removed from the grid, so that a plate current flows through the resistance *R* to heat the casing until the temperature falls to a point at which the mercury column connection between the grid and filament is broken, whereupon the heavy negative bias from *GB* is reimposed upon the valve.

Patent issued to The Marconi Co., Ltd.

LOUD SPEAKERS.

(*Application date*, 9*th February*, 1927. *No.* 290344.)

A diaphragm *D*, mounted so that it vibrates with a combined piston and flexure action, is located inside a shallow horn or resonance chamber *H* so that sound waves are propagated both from the front and rear surfaces of the diaphragm. The diaphragm *D* is constructed of a shallow cone of paper having an angle of about 120 degrees. It is supported from a rigid peripheral ring *C* by means of three lugs (not shown) which impose very little axial restraint upon the vibrating surface though they impart considerable radial rigidity.



In this way the central portion of the conical diaphragm is able to vibrate by simple piston action, *i.e.*, to move bodily to and fro without flexure, whilst on the other hand the outer portion of the diaphragm vibrates mainly by flexure about the peripheral supporting-ring *C*. This mounting is distinguished from the standard "free-edge rigid-diaphragm" type, and is stated to reproduce music with a high degree of fidelity.

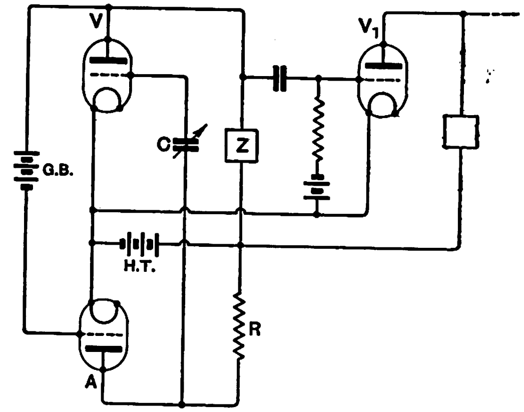
Patent issued to Charles Mahé de Chenal de la Bourdonnais.

BALANCING INTER-ELECTRODE CAPACITY.

(*Application date, 10th February*, 1927. *No.* 290,351.)

In a cascade amplifier, the inherent grid-plate capacity constitutes an input impedance on the grid, the effect of which depends, among other things, upon the nature of the impedance in the plate or output circuit. In order to provide a balancing arrangement which is independent of the nature of the plate impedance, whether inductive or otherwise, an auxiliary or compensating valve is cross-coupled to the amplifier in the manner shown in the figure.

The first amplifier *V* is coupled to a subsequent stage of amplification V_1 in any suitable manner. In series with the plate impedance *Z* is a pure resistance *R* which is also included in the plate circuit of the special compensating valve *A*, the plate of which is also variably coupled through a condenser *C* to the grid of the amplifier *V*. Conversely the plate of the latter is connected through a grid-biasing battery *GB* with the grid of the compensating valve. Both valves are fed from a common L.T. supply, the H.T. being connected to a point between the impedance *Z* and resistance *R*.



In operation the condenser *C* transfers potential variations to the grid of the valve *V* which neutralise the effect of the inherent plate-grid capacity of that valve.

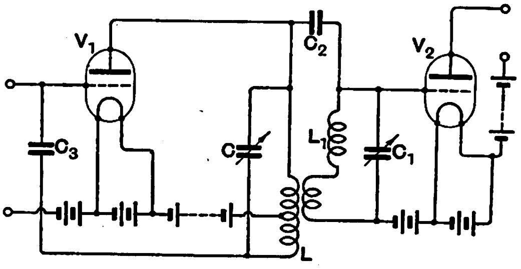
Patent issued to W. S. Smith and N. W. McLachlan.

A CONSTANT-COUPLING CIRCUIT.

(*Convention date*, (*U.S.A.*), 28*th January*, 1927. *No.* 284,587.)

Tuned intervalve couplings, although highly selective, suffer from the disadvantage that as the resonant frequency is decreased the coupling-factor is progressively increased until self-oscillation sets in. Although means have already been suggested for ensuring a constant coupling over a range of signal frequencies, the effect of the inter-electrode valve capacities still remains to be provided for. According to the invention a combined inductive and capacity coupling is provided for each valve stage, whilst the inherent valve capacities are neutralised either by using screened grids or by means of additional balancing condensers.

As shown in the figure, two H.F. valve amplifiers V_1, V_2 are connected in cascade through a step-down magnetic coupling between the coils *L*, L_1, and through a coupling condenser C_2. The amplification factor through the inductive coupling rises as the frequency is increased, whilst that due to the condenser C_2 decreases, the result of the combination giving an approximately constant ratio. In addition the effect of the inter-electrode capacity of the amplifier V_1 is eliminated by means of a neutralising condenser C_2 in series with the coil *L*.



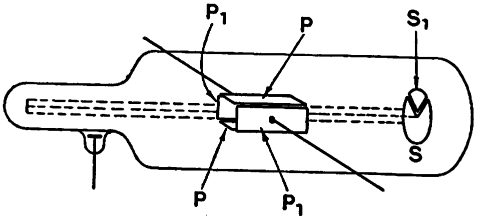
Patent issued to the British Thomson-Houston Co., Ltd.

DIRECTIONAL WIRELESS.

(*Convention date* (*Germany*), 5*th November*, 1926. *No.* 280,235.)

In order to increase the directional effect in reception, a cathode-ray tube provided with two pairs of mutually perpendicular control plates is used in combination with two directional aerials, and a cut-off segment limiting the area over which signals can be recorded on a luminescent screen. As shown in the figure, the cathode-ray stream passes through two pairs of plates *P*, *P* and P_1, P_1, to which the signal voltages from a pair of directional aerials are applied.

So long as the received signals come from stations inside, say, an angle of 14 deg., the corresponding messages are indicated by the ray striking against a luminescent sector *S* at the end of the tube. For any wider angle of incidence the control voltages throw the cathode stream off the sector *S* and on to a non-recording sector or screen S_1. The luminescent effect of the received signals on the active sector *S* may energise a photo-electric cell, adapted, in turn, to actuate a suitable indicator or recorder.

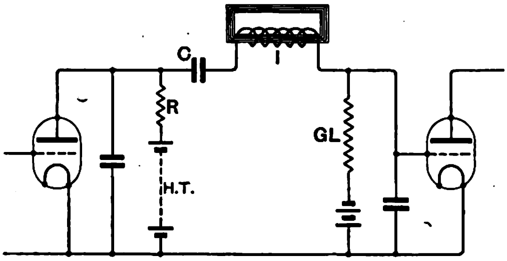


Patent issued to the Telefunken Co., Ltd.

LOW-FREQUENCY AMPLIFIERS.

(*Application date*, 23*rd February*, 1927. *No.* 291,143.)

In resistance-coupled amplifiers the use of high magnification valves in combination with high anode resistances results in a strong tendency for the amplification to fall off, particularly in the neighbourhood of 2,000 cycles and over. In order to counteract this defect, an inductive reactance is inserted in the intervalve coupling circuit, and is of such value that in combination with the valve-grid capacity it forms a resonant circuit which increases the voltage across the grid and filament of the succeeding valve and so neutralises the previous loss in amplification.



As shown in the figure the reactance *I* is in the form of an iron-cored choke inserted between the coupling condenser *C* and the grid leak resistance *GL* of the next valve, the ordinary anode coupling resistance being shown at *R*. The resonant circuit may be arranged to have a comparatively sharp cut-off for frequencies above, say, 5,000 to 6,000 cycles so as to shut out unwanted high-note sounds.

Patent issued to H. J. Round.

SINGLE-WAVE BROADCASTING.

(*Convention date* (*Germany*), 3*rd February*, 1927. *No.* 284,665.)

Relates to broadcasting networks of the kind in which a number of stations are so distributed as to serve a large area at crystal-reception strength, each station transmitting on the same wavelength under the control of a central or master station. To work such a system efficiently, it is essential to maintain the common wavelength at an absolutely constant value, otherwise intolerable heterodyning will occur. Even when this condition has been attained it is noticed that certain local zones occur, usually about midway between two stations, where owing to mutual interference between the two sets of waves, reception falls off very noticeably.

In order to prevent the formation of such "dead" areas, the carrier wave of one or more of the transmitting stations is periodically varied either as regards frequency, phase, or amplitude in a supersonic cycle, so as not to give rise to any disturbing note in the phones. Preferably the phase of the carrier-wave is varied in this manner, either by means of a constantly rotating coil or condenser or by using iron-cored chokes supplied by a variable source of saturating current.

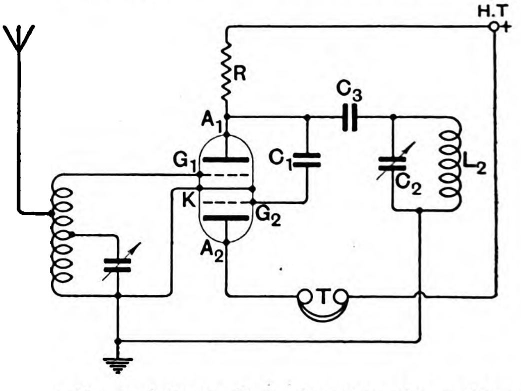
Patent issued to the C. Lorenz Co., Ltd.

HIGH-RESISTANCE COUPLINGS.

(*Application dates*, 24*th February and* 14*th October*, 1927. *No.* 291,493.)

The inventor advances a theory of valve detection and amplification based upon the use of a high plate resistance of the order of 3 to 5 megohms. He points out that in such circumstances the reactance of the external plate circuit is much greater than that of the inter-electrode capacity of the valve. The electron current through the valve may therefore be considered as divided into two parts, one passing through the plate resistance and the other charging-up the capacity of the valve electrodes. If the latter current predominates, the resultant potential variations on the plate will be approximately only 90 deg. out of phase with the grid potentials, instead of 180 deg. as is the case with a normal plate resistance of the order of 100,000 ohms. There is accordingly no appreciable feed-back to cause undesirable self-oscillation. It is stated that rectification takes place owing to the H.F. component of the plate current being smoothed out by the valve capacity, the resulting L.F. component of the modulated wave setting up potential variations across the coupling resistance.

The figure illustrates the arrangement as applied to a valve with a central filament *K*, two grids G_1, G_2, and two plates A_1, A_2. A resistance *R* of 3 megohms connects the plate A_1 to the H.T. supply, whilst a condenser C_1 connects it to the opposite grid G_2. A tuned circuit L_2, C_2 is shunted across the resistance *R* to increase the voltage variations on the plate, and hence the effective amplification, a blocking condenser C_3 preventing the electron current from being short-circuited across the inductance L_2. Incoming signals are applied across the grid G_1 and filament, whilst the telephones *T* are inserted across the second plate A_2 and the H.T. supply.



Patent issued to A. H. Midgley.

537

EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. V. OCTOBER, 1928. No. 61.

Editorial.

Olympia Radio Show, 1928.

THE National Radio Show, 1928, which was held at Olympia from September 22nd to 29th, provided an opportunity for making a comparison between the state of development of wireless to-day and the point which had been reached at the time of the Olympia Show last year, in-so-far as the broadcasting aspect of radio is concerned.

Quite apart from a consideration of detailed improvements in the design of apparatus, there are several wider influences which have been at work during the past year to contribute towards directing the future tendencies of broadcasting. It is probably correct to regard the outstanding evidence of progress to be the present state of education of the public in the appreciation of better quality in reproduction, and this improvement in the general standard of public requirements is reflected in the efforts which have been made by the manufacturers. What the radio engineer regarded as a supreme achievement in quality of reproduction a year or so ago would not be tolerated in the home of the connoisseur layman of to-day. Instead of discussion being devoted mainly to the topic of quality, as in the past, quality to-day is taken almost for granted, and problems of the moment are of a more obscure character, such as that of the correct contrast in volume in loud-speaker outputs.

Next we should mention alternative programmes, for although a year ago the idea was not new, yet the Regional Scheme, with the choice of transmissions, could not then be looked forward to with the same degree of confidence as is possible to-day. The choice of programmes, and the probable reduction in price due to royalty cuts, are accelerating the rate at which valve receivers with loud speakers are replacing the crystal sets of old. Moreover, with the disappearance of the crystal set we look forward to a revision of the present B.B.C. control-room policy, which, so long as the Corporation feels it necessary to cater specially for the crystal-set user, must mar the reception of loud speaker reproduction on account of disproportionate strength of speech and music.

Another new departure in broadcasting is picture transmission. We have at present no experience of the possibilities of still life picture transmissions as applied to broadcasting, beyond the fact that satisfactory results can be attained, but that in itself is not sufficient unless the obtaining of results is to prove of interest and benefit to the community. It seems likely, however, that picture transmissions may open up an interesting new field in the future and then, perhaps, at some more distant date, it may be succeeded by the more ambitious possibilities of a television service.

In next month's issue we propose to review those exhibits at the Olympia Show which we feel would be of special interest to our readers, dealing in particular with apparatus suitable for laboratory use.

The Design of Non-contact Thermo-junction Ammeters.

By F. M. Colebrook, B.Sc., and R. M. Wilmotte, B.A., Wireless Division, National Physical Laboratory.

Published by Permission of the Department of Scientific and Industrial Research.

Abstract.

The contact and non-contact types of thermo-junction alternating current ammeter are compared. The general principles of the design of the non-contact type are stated. Two designs embodying these principles are described with particulars as to their performance. An account is given of a particular application as a known source of radio-frequency potential difference.

1. Introduction.

By a non-contact thermo-junction ammeter is meant one in which there is no conductive connection between the heater element and the thermo-junctions. From the point of view of the measurement of current at radio-frequencies, this is a very considerable advantage for the following reason. With either type the heater element is of necessity included in the circuit carrying the radio-frequency current to be measured. With the contact type of thermo-junction ammeter, the heater is in conductive contact with the thermo-junction and thus with the galvanometer or whatever direct current instrument is employed for the measurement of the thermal E.M.F., together with its associated leads. The appreciable capacity effect of this auxiliary apparatus may, and in fact generally does, introduce an element of uncertainty into the reading of the ammeter. The reading will be found to depend to a serious extent on the position of the ammeter relative to the remainder of the circuit, particularly on its position relative to any earthed point of the system. The element of uncertainty can of course be minimised, though not necessarily eliminated, by making the point of contact of the ammeter an earthed point, and this precaution should always be taken where possible, but it is obviously preferable that the measuring instrument should be free from this restriction.

A further characteristic of the contact type, and one which is particularly disadvantageous from the point of view of experimental work, is that the destruction of the heater through over-loading means the replacement of the whole thermal element of the instrument. This is a fact of considerable economic weight, since the commercial forms of contact thermo-junction are somewhat expensive, and their use in resonant circuits makes them very liable to this kind of accident. Finally, in the matter of calibration, it is usually found that the direct current calibration depends on the relative direction of the current, so that a double calibration is required—or alternatively, calibration with low frequency alternating current.

On the other hand it must be admitted that the contact type is generally much more sensitive than the non-contact pattern. However, sensitivity is not always the most important factor.*

In non-contact thermo-junction ammeters the disturbing effect of the galvanometer need only arise from the capacity between the heater and the thermo-junctions. In the instruments described below this is of the order of 5 $\mu\mu$F., a value which is quite negligible except perhaps at ultra high frequencies.

---

* Since this was written a new pattern of non-contact vacuum thermo-junction has been put on the market. The sensitivity of this is comparable with that of the contact type and it appears to be a very satisfactory unit. Moreover, the capacity between the heater and junction is very low, being of the order of 1.5 $\mu\mu$F. without a holder. It is, however, somewhat expensive and not repairable in case of injury.

2. General Principles of Design.

Apart from any question of sensitivity a satisfactory thermo-junction ammeter should possess two further characteristics—quickness of response and stability of reading. The thermal aspect of these requirements is that the thermo-junction and heater system must attain a thermal equilibrium in a short time. This involves two features of design, (*a*) that part of the system which changes in temperature (the heater and the heated junctions) must be of small thermal capacity—the smaller the better from the present point of view; (*b*) the cold junctions must be of such large heat capacity that their temperature is not appreciably raised by the conduction of heat from the heated junctions. Both these features will be found embodied in the thermo-junction systems designed by Dr. W. J. H. Moll (Journal of Scientific Instruments, 1926, Vol. III, pp. 209–210, and *Proc. Phys. Soc.*, 1923, Vol 35, pp. 257–260), whose work on this subject constitutes the most important advance since the development of the Duddell Thermo-Galvanometer. Dr. Moll's thermo-junctions were made by rolling out thin plates of Manganin and Constantan, welded together along one edge, into a foil as thin as 0.005 mm., this foil being cut into strips to make the separate junctions. The junctions are mounted on copper pegs plugged into a sheet of metal, each peg being electrically insulated from the metal base by a very thin coating of lacquer or varnish. It was found that the time of response of such a system is limited by the inertia of the associated galvanometer rather than the heat capacity of the junctions.

The design to be described below is not claimed to be of the quality attained by Dr. Moll, but it has one important advantage—it is easy to construct and is quite sufficiently quick and stable for ordinary laboratory use.

A further essential characteristic is constancy of calibration. This involves two features of design: (*a*) the metal elements should not have any gradual change of surface conditions of a kind likely to modify appreciably their thermal radiation and absorption; (*b*) the relative position of the parts, particularly the relative position of the thermo-junctions and the heater, must not vary irreversibly under conditions of operation. In Dr. Moll's design the alloys, Constantan and Manganin, were chosen on account of their satisfactory surface constancy, while the constancy of relative position between junctions and heater was obtained by weaving the heater (an enamel insulated wire) over and under the junctions.

In the designs to be described below no attempt is made to secure constancy of surface conditions. In fact, copper is employed as one of the junction metals and the surface of this changes comparatively rapidly from an original bright and clean condition. The change, however, is not continuous and after an ageing period of a month or so, the surfaces appear to reach an effectively stable condition.

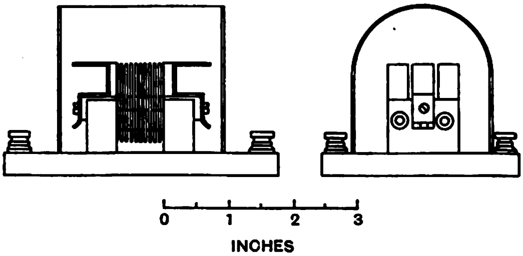


Fig. 1.

Variation of calibration attributable to relative shift of junctions and heater is avoided in two ways. In the first place the heater is maintained under a slight tension, to take up the small but by no means unimportant elongation with the use in temperature in operation. In the second place it is at such a distance from the junctions (0.5mm. or so) that the calibration is not critically dependent on this distance.

Another essential general principle of design is that the thermal system must be protected against extraneous air currents. In the designs described below the thermal systems are completely enclosed to shield them against draught. The covers are transparent or windowed for convenience of inspection.

3. Description of Two Actual Designs.

Preparation of Thermo-junctions.

Thermo-junctions of the desired characteristics can be prepared very simply by the plating process introduced by Mr. W. H.

Wilson and Miss T. D. Epps, and described by them in a paper read to the London Physical Society (*Proc. Phys. Soc.*, 1920, Vol. 32, pp. 326–339). A length of bare No. 47 S.W.G. Eureka wire is rolled out to a strip about 0.0005in. thick. This strip is wound on a frame of copper wire (about 2½in. by 3in.) which frame is then immersed vertically to about half its depth in slightly acidulated copper sulphate solution and the Eureka strip is plated with copper to a total overall thickness of about 0.001in. (There appears to be no advantage in making the coating any thicker than 0.00025in.) The frame is then washed thoroughly in tap water, followed by distilled water, and the junctions can then be removed and are ready for mounting. The copper coating may not be deposited very uniformly if the Eureka wire is not quite chemically clean. An effective, if somewhat drastic, method of cleaning the strip is to plunge that half of the frame which is to be plated, in concentrated nitric acid and then into water as rapidly as the necessary movements can be made. An alternative method of cleaning is to immerse the frame in a 5 per cent. solution of potassium hydroxide raised to boiling point and at the same time pass sufficient current through the liquid, using the frame as negative electrode and a platinum wire as positive electrode, to maintain a steady evolution of gas at the frame.

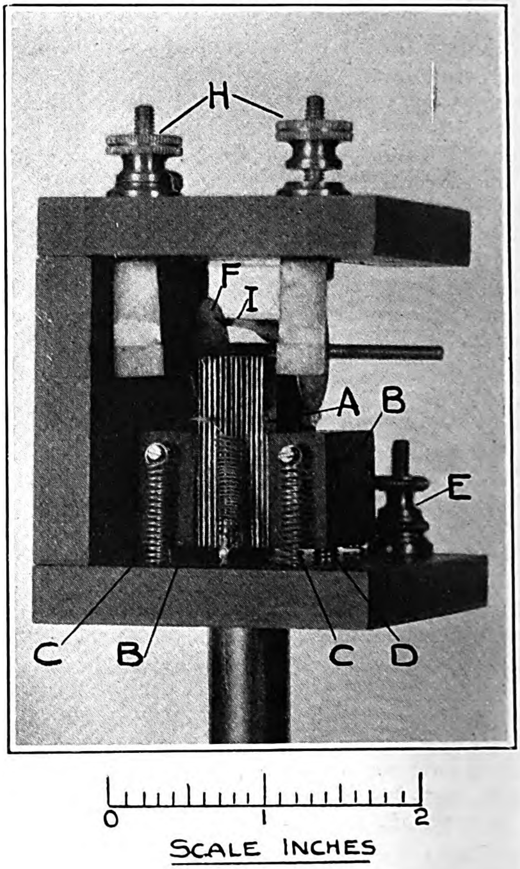


Fig. 3.

A number of different gauges of Eureka wire were tried, both in round and strip form, but in every case it was found that the slight additional sensitivity (due to lower junction resistance) was obtained at the expense of a considerable increase in the time required for thermal equilibrium, due to the increased heat capacity.

Design of Mounting.

Two different designs have been used at the National Physical Laboratory. The first is shown complete in Figure 1. The junctions are soldered, as shown in Figure 2a, to the tops of the copper stampings, shown in Figure 2b. These are stamped from hard copper sheet about 0.025in. thick. The bank of plates, separated by small fibre or ebonite insulating washers of about the same thickness, are clamped between ebonite end blocks, as in Figure 2c. These end blocks are screwed from underneath to the base

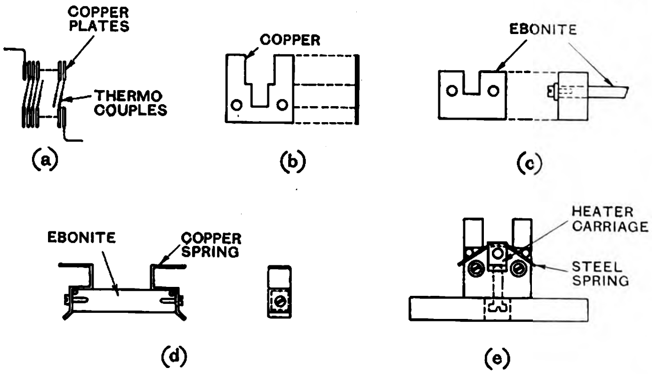


Fig. 2.

plate, which is also of ebonite. The carriage for the heater wire is shown in Figure 2d, the heater strip, about which more will be said later, being soldered to the upper surfaces of the hard copper springs, which keep it under a light tension. The heater can be passed under the junctions or over them. The latter is simpler for replacement. The carriage should fit smoothly in the grooves in the copper plates and the ebonite end blocks, and is located by means of the steel springs and the adjusting screws, as shown in Figure 2e, its height being capable of adjustment by means of the screws. In the actual models the carriage is made of ebonite, but this is liable to slight deformation by the locating springs, and bakelite would be preferable from the point of view of mechanical strength. The cover shown is made of celluloid and is located in grooves in the base plate, being held down by two small screws through flanges cemented to the end walls.

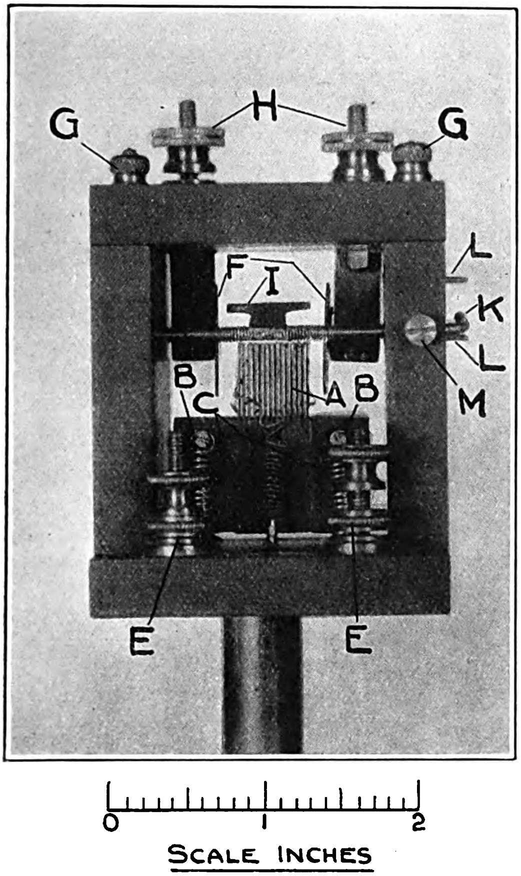


Fig. 4.

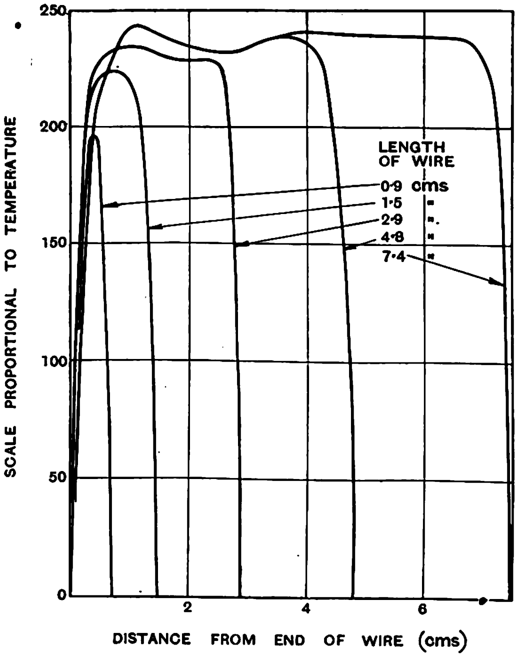


Fig. 5.—*Temperature variation along a wire carrying a current. No. 47 S.W.G. Eureka wire.*

Further design details relating to the heater strip will be found in a later section.

A second design is that shown in the photographs, Figures 3 and 4. Figure 4 shows the complete instrument and Figure 3 shows the instrument with one side of the cover removed. The junctions are soldered to copper stampings which are similar to those used in the former design but without the slot for the heater carriage. The stampings are clamped between ebonite blocks (B). These are held down to the base by means of springs (C) and supported on three screws being geometrically clamped on the cone, slot, and plane principle. One of the screws (D) can be seen in Figure 3. The thermo-junctions are connected to the terminals (E). The heater is held under a slight tension between two copper discs (F) to which it is soldered. These discs have sufficient cooling effect to permit of rapid terminal equilibrium under conditions of operation. The heater mounting and its terminals are carried by the ebonite lid, which is removable for replacement or adjustment. The distance of the heater from the junctions can be adjusted by means of the levelling screws (D). Glass windows on each side and a small mica window in the lid permit of easy inspection during adjustment.

It is often convenient to have some little degree of control over the calibration, so that a simple numerical relationship can be obtained. A very simple addition to the instrument permits of such control over a range of 10 per cent. or so. It consists of a small copper vane (I) the proximity of which to the heater can be controlled by means of the handle (K). Stops (L) prevent the possibility of damage to the heater or junctions. The vane can be clamped in position by the screw (M). This adjustment can be used if desired for correcting any small change in the calibration with time.

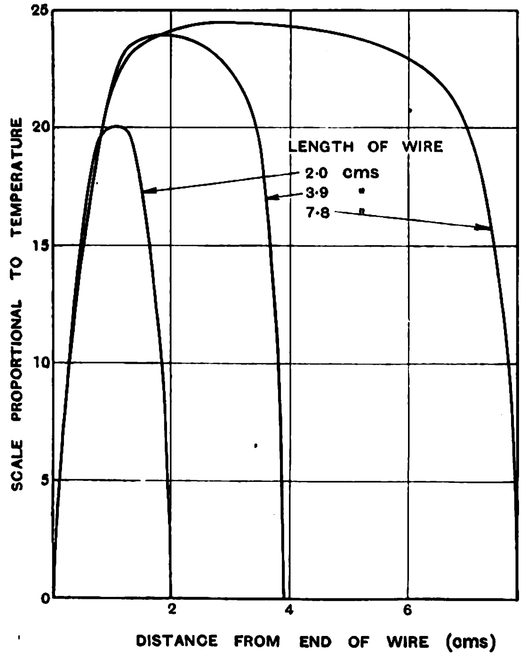


Fig. 6.—*Temperature variation along a wire carrying a current. No. 46 S.W.G. copper wire.*

This design is somewhat more compact and rigid than the other, though not quite so simple from a constructional point of view.

4. Design of Heater.

A first essential in the design of the heater element, if the instrument is intended for use at very high (radio) frequencies, is that it shall be of such a form that its resistance shall vary as little as possible with frequency. This limits the heater to wires of small diameter, preferably not exceeding No. 40 gauge, or, better still, very thin strip (about 0.0005in. or so). The strip form is better in every respect.

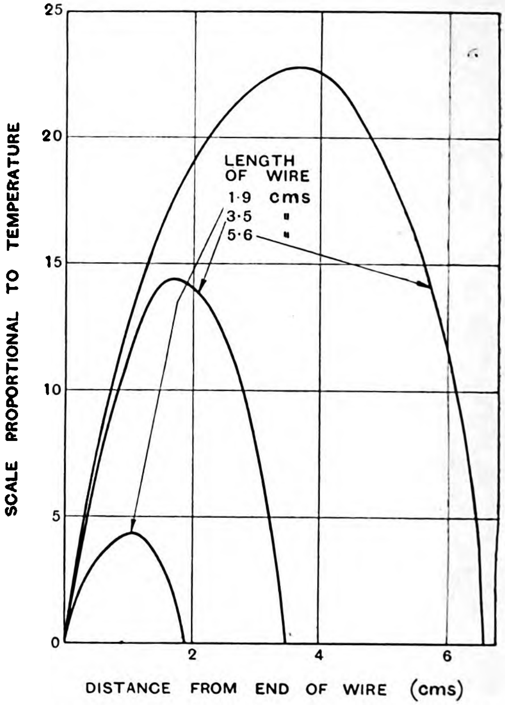


Fig. 7.—*Temperature variation along a wire carrying a current. No. 40 S.W.G. copper wire.*

High resistance material should be used, since this reduces the bulk of the heater for a given resistance. Another important reason why such material (*e.g.*, Eureka strip) should be used is that it will have a comparatively low heat conductivity. This restricts the flow of heat back to the heater-supports and thus enhances both sensitivity and stability of reading. This factor obviously imposes a lower limit on the length of the heater. The matter was investigated experimentally by traversing a single thermo-junction along the length of various heaters of different length and material at a constant height above the heaters and noting the thermal E.M.F. developed in the various positions. The ends of the heaters were clamped in sufficiently massive copper blocks to ensure constancy of temperature.

Results obtained for heaters of various lengths of No. 47 Eureka wire, No. 46 copper wire, and No. 40 copper wire are shown in Figures 5, 6, and 7. The superiority of the Eureka wire is obvious. Figure 7 further shows the loss of sensitivity which will be caused by end cooling if low resistance heaters of insufficient length are used. Even if No. 46 copper is used the length should not be less than 4 cms.

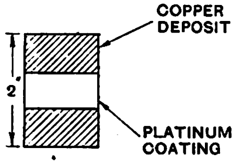


Fig. 8.

For heaters of very high resistance, platinised mica strip can be used. This is prepared by splitting the mica sheet to 0.0005 to 0.001in. in thickness and rubbing down with fine glass paper to give a matt surface. This is then platinised, using the colloidal preparation known commercially as "liquid silver." The thickness of coating can be varied within wide limits by means of successive thin coatings. The ends of the sheet can be electrically plated with copper to ensure good terminal contact (see Figure 8). The sheet can then be cut into strips of suitable width. Such heaters require a somewhat different mounting from those already described, some form of light copper clamp being substituted for the sheet copper soldering surfaces of the other mountings. Resistances varying from ten ohms to several thousands of ohms can be obtained in strips about 1½in. by 1/16th in. in this manner.

No. 47 Eureka wire rolled of a strip 0.0005in. thick is the most generally useful heater, carrying currents up to 0.2 ampere. It burns out at about half an ampere. No. 47 copper similarly rolled to strip will carry about one ampere.

The designs described are not very suitable for the measurement of currents greater than an ampere, as the increasing bulk of the heater leads to loss of watt sensitivity and sluggishness in action.

5. Effect of Variation of Distance between Heater and Junctions.

The apparatus used for the determination of the end effect described in the preceding section was applied to an investigation of the variation of the thermal E.M.F. with the distance between the heater and the junctions. The curve shown in Figure 9 records the mean values of a large number of observations. The somewhat irregular variation for small distances was confirmed by repetitions. This irregular variation is probably attributable to the fact that heat transference to the junction is affected in at least two ways, *i.e.*, radiation and convection. (The thermo-junction was above the heater in these measurements.) The curve shows that for distances less than about 0.3 mm., the calibration will be rather sensitive to small variations of distance. From the point of view of stability of calibration it appears preferable to sacrifice some degree of sensitivity and adjust to a separation of half a millimetre or so, where the variation with distance is comparatively slow.

It can easily be shown that for such distances the heat transference by convection is negligible, for the thermal E.M.F. is only affected to a few per cent. by inverting the system.

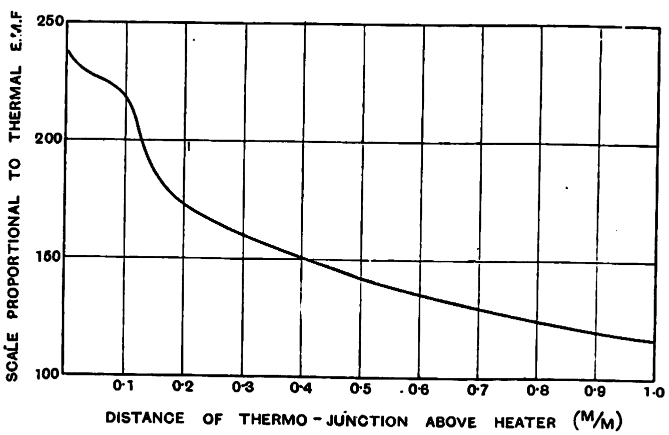


Fig. 9.—*Curve showing relation between the thermal E.M.F. produced in a copper-Eureka junction and its distance above a* 0.002 *in. diameter. Platinum wire carrying a constant current.*

6. Calibration.

The calibration with direct current shows that the instrument follows very approximately a square law. A typical calibration curve is given in Figure 10. Where absolute values are not required the square law assumption can be made with sufficient accuracy for most purposes. This is more particularly true for smaller values of heater temperature. The instrument is, therefore, more accurately square law in association with a reflecting galvanometer than with a pointer galvanometer or milli-voltmeter. With junctions constructed as described the thermo-junction group will have a resistance of the order of ten to twenty ohms, and a measuring instrument having a resistance of this order should, therefore, be used with it.

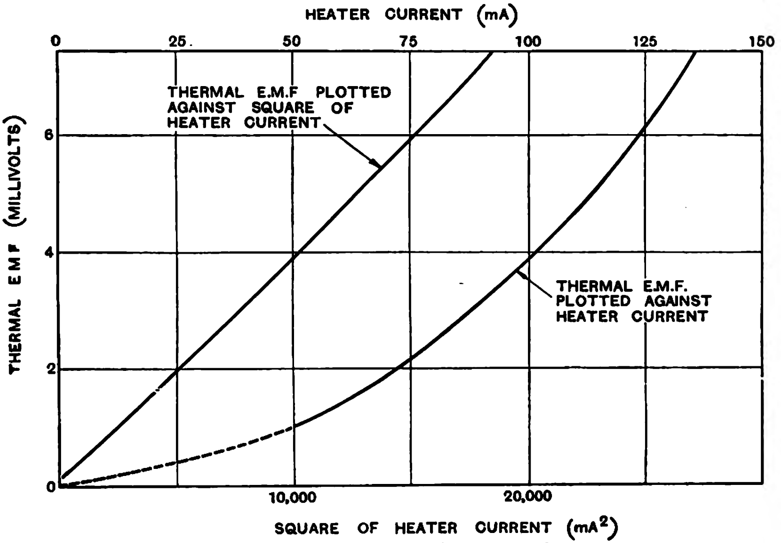


Fig. 10.—*Calibration curve for thermal ammeter.*

The actual sensitivity varies from 10 to 20 milli-volts per watt consumed in the heater. As already pointed out, this is very low compared with that obtainable from a vacuum contact thermo-junction, which will generally be of the order of several hundred milli-volts per watt. However, sensitivity is not always a very important factor, and in many cases, particularly in experimental work, ease of repair and heater replacement will outweigh the drawback of low sensitivity.

7. Use as a source of known radio-frequency potential differences.

A particular application that has been made of the above described thermo-junction system is that illustrated diagrammatically in Figure 11. Leads of thin copper strip are soldered to the heater just outside the length that lies directly under the junctions. These are used as potential leads, giving a source of radio-frequency potential of from a tenth of a volt to about a volt. This arrangement has the advantage that the current is measured along the length of the actual resistance (the heater) which constitutes the source of potential difference, and thus eliminates any uncertainty due to a possible variation of the current in the other parts of the circuit.

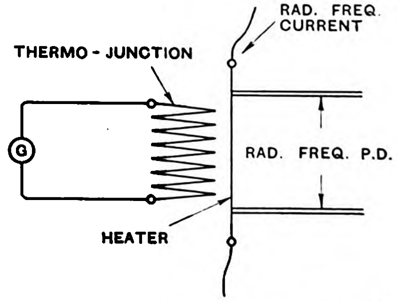


Fig. 11.—*Use of non-contact thermo-junction ammeter as a source of known potential difference at radio-frequencies.*

Effect of Anode-grid Capacity in Detectors and L.F. Amplifiers.

By W. B. Medlam, B.Sc., A.M.I.E.E.

IN radio receivers the couplings between circuits which should be electrically separate make it almost impossible to predict exactly the performance of a complete receiver from a knowledge of the performance of its components. There are many sources of undesirable couplings, the most important of these are:

(1) The feed-back effect. This is the modification of the output circuit of a valve by the presence of the input circuit, due to anode-grid capacity.

(2) The input load effect. This is the modification of the input circuit of a valve by the presence of the output circuit, also due to anode-grid capacity.

(3) Direct inductive or capacity coupling between components.

(4) Couplings due to common leads in the wiring of the receiver.

(5) Resistance couplings due to the use of common batteries, or common mains units.

Considering the above effects in inverse order, (5) has become acute with the extended use of comparatively high resistance mains units, and moving coil speakers necessitating large outputs. The effect of this form of coupling can be eliminated by the use of anode feed resistances and condensers.[*] The effects of (4) have been dealt with recently in *The Wireless World*.[†] The elimination of effects due to (3) is a matter of the construction, disposition, and shielding of components. The effects of couplings (1) and (2) have been overcome in H.F. amplifiers by the use of the screened grid valve and neutrodyne circuits; but their effects in the detector and L.F. amplifying stages have received very little quantitative attention, and circuits designed to cut them out do not appear to have been developed. In the present article the effects of the anode-grid capacity on the audio frequency characteristic of the detector and L.F. stages are shown to be serious, and suggestions are made for their elimination.

Effect of Anode-Grid Capacity in Detector Stage.

Equivalent Circuit of Detector.—From the point of view of the input voltage, the input circuit of a curvature detector is equivalent to the arrangement of Fig. 1. An input E.M.F., e, is injected into the original input circuit C, L, r. When this circuit is attached to the valve it is modified by the connection of the anode-grid capacity, C_{ga}; the internal resistance of the valve, r_a; a capacity, C_a between anode and filament; a shunt capacity which becomes a part of C, and a resistance due to this capacity, the effect of which may be included in r. The radio frequency load in the anode circuit of a detector is always capacitative, the impedance of C_a being much less than that of the external load resistance or inductance at the radio frequency; also, in general, the reactance of C_a is much smaller than r_a. Thus, except for a detuning effect, which can be corrected by adjustment of C, the capacity C_{ga} leads to but slight resistance loading of the input.

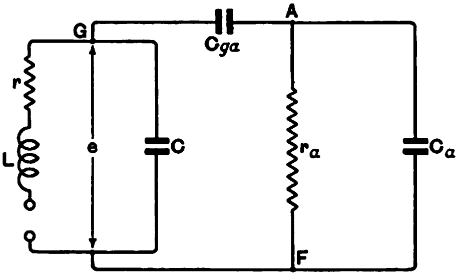


Fig. 1.—*Equivalent input circuit of detector as modified by anode-grid capacity.*

The position as regards the feed-back effect is, however, much more serious. As the three electrode valve is not a perfect rectifier there will be a radio frequency E.M.F. (μe_g) in the anode circuit when a voltage (e_g) is applied to the grid. The value of μ is, of course, quite different from the normal value for the valve under amplifying conditions. Experimental results indicated a value of μ between 0.1 and 0.2 for an anode bend rectifier adjusted for optimum rectification with a high resistance as external anode load.* Although the radio frequency E.M.F. in the anode circuit may be considerably less than that applied to the grid it has, nevertheless, a relatively large effect on the audio frequency characteristic of the detector, particularly on the lower audio frequencies, as is shown later. If the grid bias or H.T. are considerably below their values for maximum efficiency of rectification, so that the valve begins to amplify, then owing to the consequent increase in μ, it may be impossible for the valve to give any reasonable output on the lowest audio frequencies, and the effective modulation in the resultant input may rise to 100 per cent. with quite low modulations (say below 20 per cent.) in the original input to the valve. The full reasons for this are rather complex, and before dealing with the action mathematically, they may be stated, roughly, as follows: The equivalent circuit of the detector for the E.M.F. μe_g is shown in Fig. 2. As before, the external anode circuit load is omitted as it has negligible effect on the radio frequency current distribution. The circuit in Fig. 2 for μe_g is quite different from that in Fig. 1 for the input voltage e owing to the different location of the E.M.F. In Fig. 2 the E.M.F. μe_g sets up a voltage across the input circuit in partial anti-phase to the signal voltage. The magnitude (and phase) of this feed-back voltage depends on the impedance of the input circuit in relation to the reactance of C_{ga}. On the frequency to which the input circuit is tuned, say to the carrier frequency, its impedance is much larger than the reactance of C_{ga}, and a large share of the feed-back voltage falls across it, leading to the maximum drop in the input. On the side band frequencies more remote from the carrier the impedance of an input circuit of reasonable efficiency falls to a value which is not large compared with the reactance of C_{ga}, and the feed-back voltage across the input circuit is less. Thus, the input is maintained at a higher value on the side bands than on the carrier, leading to an increase in the effective modulation.

---

[*] "Low-frequency Oscillation," *The Wireless World*, January 4th, 1928.

[†] "Scientific Wiring," April 25th, 1928.

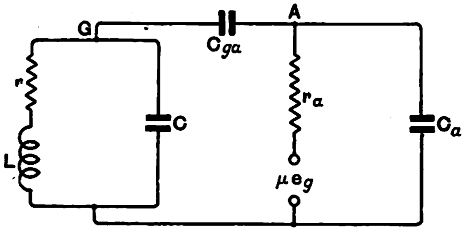


Fig. 2.—*Equivalent output circuit of detector as modified by anode-grid capacity.*

Tuning Conditions.—With the input circuit connected to the valve and the filament off to cut out the action of μe_g, the tuning capacity for the input voltage e is C (which includes the grid-filament capacity of the valve) plus the capacities C_{ga} and C_a in series. That is, the input circuit tunes to the input voltage with a capacity $C + C_x$ in which

$$C_x = C_{ga}.C_a/(C_{ga} + C_a) \quad .. \quad (1)$$

If the valve filament is now switched on the input circuit is distuned to the anode circuit E.M.F., μe_g, although it remains tuned to the input voltage, e. The impedance of the input circuit to μe_g is that given with a tuning capacity C only—a capacity less than that required for resonance. That is, the input circuit behaves as an inductive reactance to μe_g when the frequency of μe_g (and e) is that giving resonance to the input voltage. Suppose this frequency to be that of the carrier. Then on a neighbouring side band it is possible for the input circuit C, L, r. to resonate for μe_g and offer its maximum impedance to this voltage, and at the same time to be distuned to the input voltage e. On this frequency the effective input will rise or fall depending on the phase of the feed-back voltage. Evidently this parallel resonance condition can only occur on an upper side band.

There is another critical condition operative only on a lower side band. On a certain side band frequency the condition for series resonance of the input circuit with C_{ga} will occur for μe_g, again throwing a large feed-back voltage across the input. The tuning condition for this is

---

* "The Performance of Valve Detectors," Medlam and Oschwald, Journal I.W.T., Vol. 1, No. 4.

$$\omega^2(C + C_{ga})\,L = 1 \qquad .. \quad (2)$$

As the capacity $C + C_{ga}$ is slightly greater than the input carrier tuning capacity $C + C_x$, series resonance can only occur when the frequency is below the carrier frequency, *i.e.*, on a *lower* side band.

To determine exactly where these two critical conditions occur, let the carrier frequency be $\omega_c/2\pi$, and the modulation frequency $m/2\pi$. Then, for parallel resonance with μe_g on an upper side band

$$\omega^2_c\,(C + C_x)\,L = (\omega_c + m)^2CL \qquad .. \quad (3)$$

assuming the input circuit resonates on ω_c to e.

Thus $$C + C_x = (1 + m/\omega_c)^2C \qquad .. \quad (4)$$

As m/ω_c is small compared with unity $(1 + m/\omega_c)^2$ is very nearly equal to $1 + 2m/\omega_c$,

and $$m/\omega_c \doteqdot C_x/2C \qquad .. \qquad .. \quad (5)$$

If N is the audio frequency, and n the radio frequency (carrier), equation (5) may be written

as $$N/n = C_x/2C \qquad .. \qquad .. \quad (6)$$

Substitution of average numerical values in the last equation shows that parallel resonance can occur on Broadcast frequencies only when C is comparatively large. For example, if $n = 800$ kilocycles, $N = 8{,}000$ cycles, $C_{ga} = 5\mu\mu F$, $C_a = 100\mu\mu F$, then $C_x = 4.8\mu\mu F$, and the value of C is $240\mu\mu F$. For values of C less than that given by equation (6) the input circuit C, L, r, behaves (towards μe_g) as an inductance reactance to the whole side band range.

For series resonance with C_{ga} on a lower side band of frequency $(\omega_c - m)/2\pi$ the condition is

$$\omega_c^2(C + C_x)\,L = \omega_c^2(1 - m/\omega_c)^2(C + C_{ga})\,L, \qquad .. \quad (7)$$

i.e., $$m/\omega_c(= N/n) = C^2_{ga}/2(C + C_{ga})(C_a + C_{ga}) \qquad .. \quad (8)$$

Substitution of average numerical values shows that the critical value of the audio frequency given by (8) is comparatively low. For example, on a carrier of 800 kilocycles, with $C_{ga} = 5\mu\mu F$ and $C = C_a = 100\mu\mu F$., the value of $N = 900$ cycles. On the lower side band corresponding to this audio frequency a resonant rise of the feed-back voltage occurs across the input circuit. The precise effect of this depends upon the phase of the voltage.

Resultant input under Feed-back Conditions.—Assuming the value of C to be less than that required for parallel resonance to occur within the normal side band region, the input circuit may be represented by an equivalent inductance of value L_e, so far as μe_g is concerned, and the equivalent circuit is as shown in Fig. 3, in which e_r is the instantaneous value of the feed-back voltage across the input. If the original input between grid and filament is

$$e = E \sin \omega t, \qquad .. \qquad .. \quad (9)$$

where $$\omega = \omega_c \pm m, \qquad .. \qquad .. \quad (10)$$

the upper (in this case the positive) sign being taken for the upper side band, and the lower sign for the lower one, the resultant voltage between grid and filament at any instant is given by

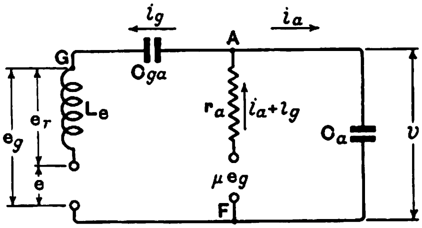


Fig. 3.—*Equivalent output circuit of detector when the input circuit is tuned to the original input voltage.*

$$e_g = e - e_r \qquad .. \qquad .. \quad (11)$$

It is assumed that the anode circuit E.M.F. (μe_g) at any instant during the final steady state is always μ times the resultant grid voltage (e_g) existing at the same instant.

The circuit equations for μe_g are

$$\frac{dv}{dt} = \frac{i_a}{C_a} = \frac{i_g}{C_{ga}} + L_e\frac{d^2i_g}{dt^2} = \mu\frac{de_g}{dt} - r_a\left(\frac{di_a}{dt} + \frac{di_g}{dt}\right) \quad (12)$$

After eliminating i_a from the above equations, the following results :—

$$C_aL_er_a\frac{d^3i_g}{dt^3} + L_e\frac{d^2i_g}{dt^2} + r_a\left(1 + \frac{C_a}{C_{ga}}\right)\frac{di_g}{dt} + \frac{i_g}{C_{ga}} = \mu\frac{de_g}{dt} \qquad .. \quad (13)$$

The feed-back voltage

$$e_r = \omega L_e i_g\,. \qquad .. \qquad .. \qquad .. \quad (14)$$

Eliminating i_g from (13) by means of (14) gives

$$\frac{r_a C_a}{\omega}\frac{d^3e_r}{dt^3}+\frac{1}{\omega}\frac{d^2e_r}{dt^2}+\frac{r_a}{\omega L_e}\left(1+\frac{C_a}{C_{ga}}\right)\frac{de_r}{dt}$$
$$+\frac{e_r}{\omega C_r L_e}=\mu\frac{de_g}{dt} \quad .. \qquad .. \ (15)$$

But from (9) and (11) the resultant grid voltage is given by

$$e_g=-e_r+E\sin\omega t \qquad .. \ (16)$$

Eliminating e_r from (15) by means of (16) gives, after rearrangement of terms,

$$\frac{r_a C_a}{\omega}\frac{d^3e_g}{dt^3}+\frac{1}{\omega}\frac{d^2e_g}{dt^2}+\left[\frac{r_a}{\omega L_e}\left(1+\frac{C_a}{C_{ga}}\right)+\mu\right]\frac{de_g}{dt}$$
$$+\frac{e_g}{\omega C_{ga}L_e}=E\left(\frac{1}{\omega C_{ga}L_e}-\omega\right)\sin\omega t$$
$$+E\left\{\frac{r_a\omega\left(1+\dfrac{C_a}{C_{ga}}\right)}{\omega L_e}-\omega^2 C_a r_a\right\}\cos\omega t \ (17)$$

The steady state solution for e_g is

$$e_g=E\sqrt{\frac{k^2{}_1+k^2{}_2}{k^2{}_1+(\mu+k_2)^2}}\sin\Big[\omega t$$
$$-\omega t\tan^{-1}\frac{k_2}{k_1}-\tan^{-1}\frac{\mu+k_2}{k_1}\Big], \ .. \ (18)$$

in which $k_1=\dfrac{1}{\omega^2 C_{ga}L_e}-1,$ .. (19)

and $k_2=\dfrac{r_a}{\omega L_e}\left(\dfrac{C_a}{C_{ga}}-1\right)-\omega C_a r_a.$ .. (20)

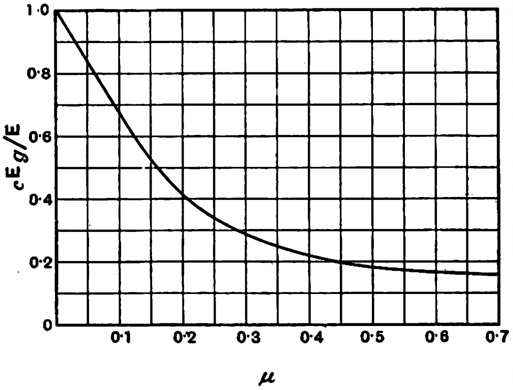


Fig. 4.—*Relation between μ of detector and the ratio of resultant to original input voltage on the carrier frequency, showing the effect of feed-back.*

The equivalent inductance, L_e, has now to be evaluated.

To μe_g the impedance of the input circuit C, L, r, when untuned is given by

$$Z=\omega L\Big/\omega C\sqrt{r^2+\left(\frac{1}{\omega C}-\omega L\right)^2}, \quad .. \ (21)$$

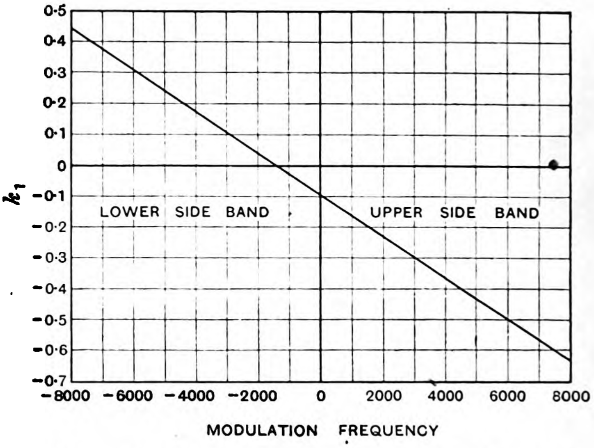


Fig. 5.—*Relation between k_1 and modulation frequency.*

when $r^2<<\omega^2L^2$; or, replacing ω by $\omega_c(1\pm m/\omega_c)$, and dividing through by $1\pm m/\omega_c$, gives

$$Z=\omega_c L\Big/\sqrt{(\omega_c C r)^2+\left\{\left(1\mp\frac{m}{\omega_c}\right)-\left(1\pm\frac{m}{\omega_c}\right)\omega_c{}^2CL\right\}^2} \ .. \ (22)$$

If the input is tuned to the carrier frequency $(\omega_c/2\pi)$ for the original input e, this condition, from (1), is

$$\omega_c^2(C+C_x)\,L=1 \quad .. \qquad .. \ (23)$$

Eliminating C between (23) and (22) gives

$$Z=\omega_c L\Big/\sqrt{\left[\mp 2\frac{m}{\omega_c}+\left(1\pm\frac{m}{\omega_c}\right)\omega_c^2C_xL\right]^2+\frac{r^2}{\omega_c{}^2L^2}\left(1-\omega_c^2C_xL\right)^2} \quad .. \ (24)$$

In general the effect of the resistance term $r^2(1-\omega_c^2C_xL)^2/\omega_c^2L^2$ may be neglected, as $\omega_c^2C_xL$ is always appreciable owing to the initial assumption that parallel resonance does not occur. In this case the equivalent inductance of the circuit is given by

$$L_e=L\Big/\left[\mp 2\frac{m}{\omega_c}+\left(1\pm\frac{m}{\omega_c}\right)\omega_c^2C_xL\right]. \qquad (25)$$

Substituting the value of L_e from (25) in (19) and (20), the value of k_1 becomes approximately

$$k_1 = \mp \frac{2N/n}{\omega_c^2 C_{ga} L} - \frac{C_{ga}}{C_{ga} + C_a}, \quad .. (26)$$

and, very closely,

$$k_2 = \mp 2\frac{N}{n} \cdot \frac{r_a}{\omega_c L}\left(1 + \frac{C_a}{C_{ga}}\right). \quad .. (27$$

The above values of k_1 and k_2 inserted in equation (18) give the amplitude and phase of the resultant grid voltage on any side band frequency. To avoid confusion over the double sign in (26) and (27) the values may be restated as follows:

For the carrier frequency:

$$k_1 = - C_{ga}/(C_{ga} + C_a), \quad .. (28)$$

and

$$k_2 = 0. \quad .. \quad .. \quad .. (29)$$

For all upper side bands corresponding to a modulation frequency N,

$$k_1 = - \frac{2N/n}{\omega_c^2 C_{ga} L} - \frac{C_{ga}}{C_{ga} + C'} \quad (30)$$

and

$$k_2 = - 2\frac{N}{n} \cdot \frac{r_a}{\omega_c L}\left(1 + \frac{C_a}{C_{ga}}\right). \quad .. (31)$$

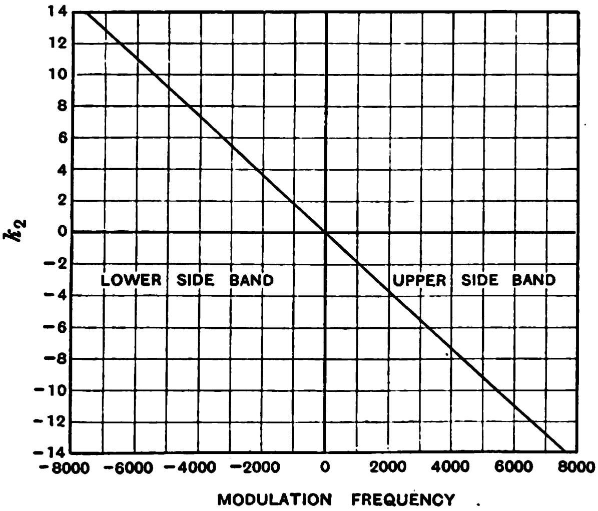


Fig. 6.—*Relation between k_2 and modulation frequency.*

For all lower side bands corresponding to a modulation frequency N,

$$k_1 = \frac{2N/n}{\omega_c^2 C_{ga} L} - \frac{C_{ga}}{C_{ga} + C'} \quad .. (32)$$

and

$$k_2 = 2\frac{N}{n} \cdot \frac{r_a}{\omega_c L}\left(1 + \frac{C_a}{C_{ag}}\right) \quad .. (33)$$

Numerical Example.

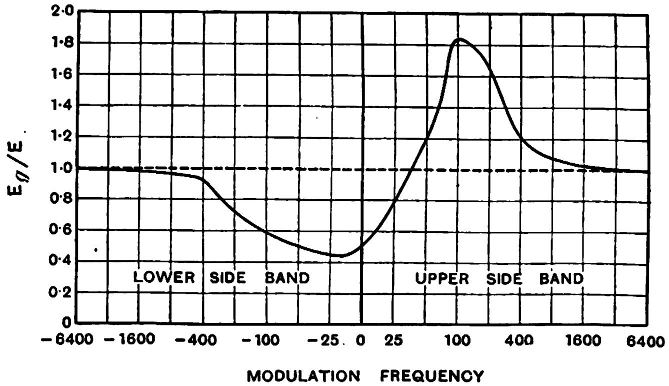


Fig. 7.—*Relation between modulation frequency and the ratio of resultant to original input voltage to a detector, showing the effect of feed-back.*

To show the order of magnitude of the interference of the feed-back action on the audio frequency characteristic of the detector a numerical example will be worked out, taking average values applicable to Broadcast receivers. Let $C_{ga} = 5\mu\mu F.$, $C_a = 50\mu\mu F.$, $\omega_c L = 1{,}500$ ohms, $\omega_c = 5 \times 10^6$, corresponding to a wavelength of 375 metres, and radio frequency $n = 800$ kilocycles. For an audio frequency modulation $N = 8{,}000$ cycles, $n/N = .01$, and the value of k_1 is $- 0.624$ for the upper side band, 0.442 for the lower side band, and $- 0.091$ for the carrier.

To determine the value of k_2 an average value of r_a must be assumed. Under the conditions of operation here considered r_a will be much greater than the nominal value for the valve, and a value $r_a = 100{,}000$ ohms will be taken. The substitution of other values for r_a will show that the results are very little affected indeed by large changes in r_a. From (31), (33) and (29), the value of k_2 is $- 14.7$ for the upper side band, 14.7 for the lower side band, and zero for the carrier.

Amplitude of Resultant Grid Voltage.—From (18) the amplitude of the resultant grid voltage is

$$E_g = E\sqrt{\frac{k_1^2 + k_1^2}{k_1^2 + (\mu + k_2)^2}}. \quad \ldots (34)$$

Substituting the numerical values of k_1 and k_2 in (34) gives the resultant amplitude of the upper side band

$$_uE_g = E\sqrt{\frac{0.39 + (14.7)^2}{0.39 + (\mu - 14.7)^2}}, \quad (35)$$

of the lower side band

$$_lE_g = E\sqrt{\frac{0.19 + (14.7)^2}{0.19 + (\mu + 14.7)^2}}, \quad (36)$$

and of the carrier

$$_cE_g = .091E/\sqrt{.00083 + \mu^2}. \quad \ldots (37)$$

Effect of μ *on Voltage Amplitude of Side Bands.*—The form of the numerical results given above shows that when μ is less than unity the extreme side band voltages are each practically equal to the corresponding input voltage amplitude of the original input, *i.e.*, approximately,

$$_uE_g = {}_lE_g = E,$$

and the input is unaffected by the feed-back action so far as amplitude is concerned, but there is a large phase shift of the resultant input, as is shown later.

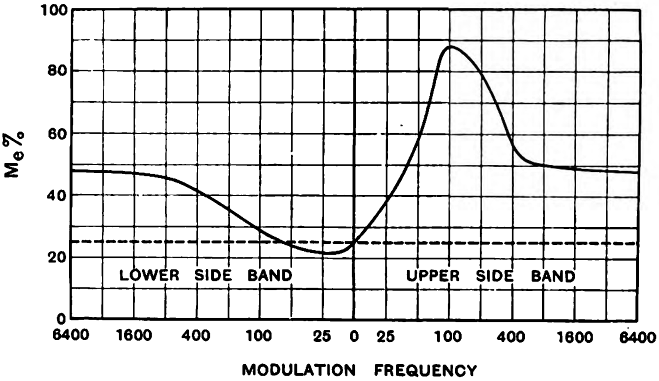


Fig. 8.—*Variation, due to feed-back, of effective modulation in resultant input to a detector (for a constant original input modulation of 25 per cent.) with the modulation frequency.*

If the detector is badly adjusted so that the value of μ is very considerably increased, the resultant grid voltage tends to increase on the extreme upper side band and to decrease on the extreme lower one.

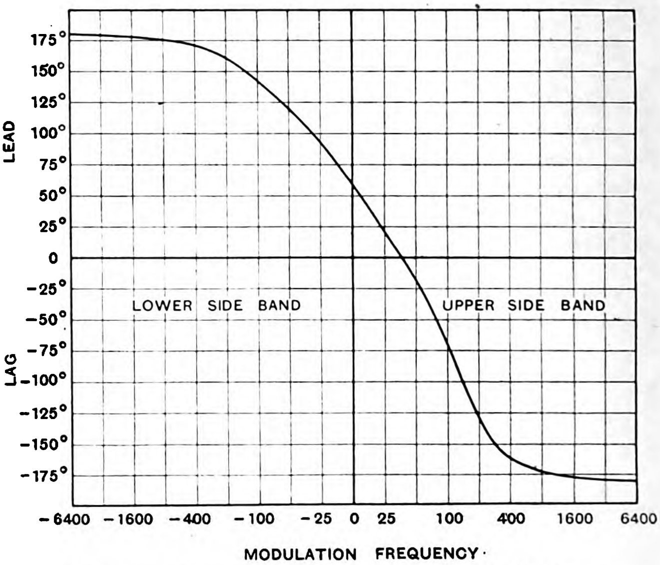


Fig. 9.—*Phase shift, due to feed-back, of side band frequencies in a detector.*

On the carrier frequency the relation between μ and the ratio $_cE_g/E$ is shown graphically in Fig. 4. Taking an average value of $\mu = 0.15$, the feed-back reduces the input to about 50 per cent.

Audio Frequency Characteristic. — The numerical relations between k_1 and k_2, and the modulation frequency (N), are given in Figs. 5 and 6 respectively. The values of k_1 and k_2 were calculated using the same numerical values of capacity, inductance, and carrier frequency, as stated above, and with $\mu = 0.15$.

The corresponding relation between E_g/E and N is shown in Fig. 7. For frequencies above ± 500 cycles the curve becomes asymptotic to the horizontal line for which E_g/E is unity. The same curve may be taken to represent the audio frequency characteristic of the detector assuming the characteristic to be level in the absence of C_{ga}. The characteristic does not settle down until the audio frequency exceeds about 1,000 cycles, and the two side bands corresponding to any given modulation frequency below 1,000 cycles are unequal; they may be in any ratio up to 3 to 1 in this particular case.

If the value of C_a is reduced the disturbance of the input extends to higher audio frequencies than in the above numerical case where $C_a = 100\mu\mu F$.

Effective Modulation in Grid Voltage.—As the feed-back affects the carrier and side band voltages in different degree, the effective modulation in the resultant input to the grid of the valve is altered from its value in the original input. If M is the original modulation, the effective modulation is given by

$$M_e = M\sqrt{\frac{\left\{1+\mu^2\left(1+\frac{C_a}{C_{ga}}\right)\right\}^2(k_1^2+k_2^2)}{k_1^2+(\mu+k_2)^2}} \quad . \quad (38)$$

Taking the same average numerical values as before, the variation of the effective modulation with the modulation frequency is shown in Fig. 8, assuming a constant original input modulation of 25 per cent.

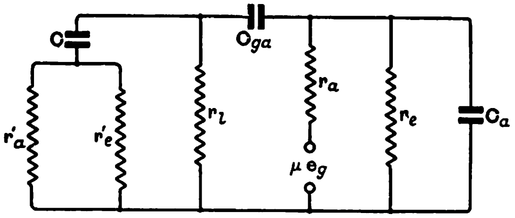


Fig. 10.—*Equivalent output circuit of R–C amplifier as modified by feed-back.*

On side bands more than about 800 cycles from the carrier M_e is practically constant at about 50 per cent., *i.e., at double the input modulation*; on side bands closer to the carrier M_e varies from 24 per cent. to about 90 per cent.

These results indicate the very important effect the feed-back action may have in causing distortion on deep input modulations, especially in the region of particular modulation frequencies.

Really, the frequency characteristic of a detector is unstable below about 1,000 cycles, as the slightest change in the various capacity values produces disproportionate changes in the effective modulation.

Phases of Side Band Voltages.—The resultant grid voltage lags behind the original input voltage by an angle

$$\tan^{-1} k_2/k_1 + \tan^{-1} (\mu + k_2)k_1.$$

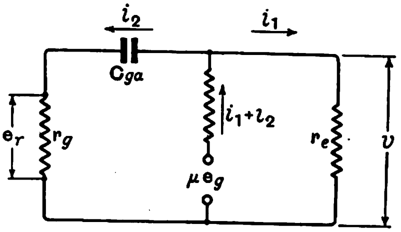


Fig. 11.—*The circuit of* Fig. 10 *simplified.*

Values of this phase displacement of the modulation frequencies, for the circuit values already stated, are shown in Fig. 9.

Feed-back in L.F. Amplifier.

As regards the anode circuit E.M.F., the equivalent circuit of a resistance-capacity coupled amplifier is as shown in Fig. 10, in which r_e is the external resistance in the anode circuit, shunted by a small stray capacity C_a; r_a is the internal resistance of the valve; C_{ga} the anode-grid capacity, and r_l the resistance of the grid leak. As the coupling capacity, C, to the preceding stage has a comparatively low reactance to the audio frequency, it is necessary to include the internal resistance, r'_a, and the external resistance r'_e, of the preceding stage as a part of the input circuit of the stage under consideration. In fact, as r'_e will be, in

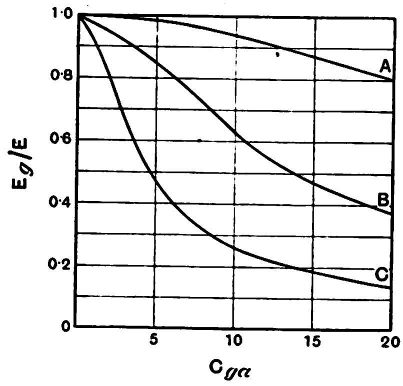


Fig. 12.—*Variation with anode-grid capacity of the ratio of resultant to original input voltage, for first and subsequent stages of R–C amplification.*

general, much less than r_e or r'_e, the effective input resistance, for the E.M.F. μe_g, will be about equal to the internal resistance of the valve in the preceding stage.

In the following analysis the small effect of the stray capacity, C_a, on the anode potential will be neglected, and C will be assumed to be sufficiently large for its reactance to be negligible on the higher audio frequencies. Then, taking the resultant of the three parallel resistances r'_a, r'_e, r_i as the effective input resistance r_g, the circuit reduces to that shown in Fig. 11.

The circuit equations for μe_g are

$$v = r_e i_1 = \mu e_g - r_a(i_1 + i_2) = r_g i_2 + \frac{1}{C_{ga}}\int i_2 dt.$$

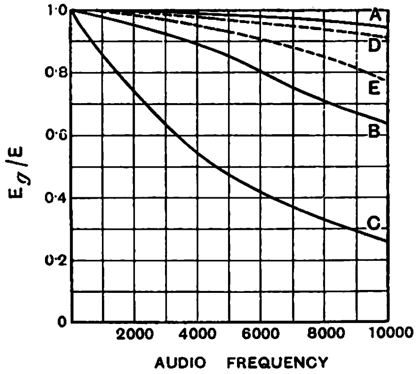


Fig. 13.—*Variation with audio-frequency of the ratio of resultant to original input voltage, for first and subsequent stages of R–C amplification.*

Eliminating i_1 from the above equations, and differentiating,

$$\left(r_g + \frac{r_a r_e}{r_a + r_e}\right)\frac{di_2}{dt} + \frac{i_2}{C_{ga}} = \frac{\mu r_e}{r_a + r_e}\frac{de_g}{dt} \quad .. \quad (39)$$

The feed-back voltage between grid and filament

$$e_r = r_g i_2 \quad .. \quad .. \quad .. \quad (40)$$

Eliminating i_2 between (40) and (39) gives

$$\left\{1 + \frac{r_a r_e}{r_g(r_a + r_e)}\right\}\frac{de_r}{dt} + \frac{e_r}{C_{ga} r_g} = \frac{\mu r_e}{r_a + r_e}\frac{de_g}{dt} \cdot (41)$$

If the original signal voltage between grid and filament is

$$e = E \sin \omega t, \quad .. \quad .. \quad .. \quad (42)$$

then the resultant input voltage (e_g) is given by

$$e_g = -e_r + E \sin \omega t \quad .. \quad .. \quad (43)$$

Eliminating e_r between (43) and (41), and writing A for $r_g + \frac{r_a r_e}{r_a + r_e}$, gives

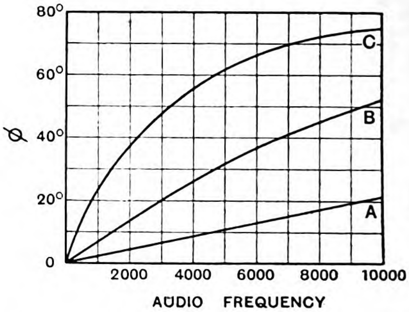


Fig. 14.—Relation between the audio frequency and the phase shift of the resultant input voltage for a R–C amplifier.

$$\left(A + \frac{\mu r_g r_e}{r_a + r_e}\right)\frac{de_g}{dt} + \frac{e_g}{C_{ga}} = \frac{E}{C_{ga}}\sin \omega t$$

$$+ A\omega E \cos \omega t = E\sqrt{\frac{1}{C^2_{ga}} + \omega^2 A^2}\sin\Big(\omega t$$

$$+ \tan^{-1} A\omega C_{ga}\Big) \ldots \quad .. \quad (44)$$

The solution of (44) for e_g is

$$e_g = E\sqrt{\frac{\frac{1}{\omega^2 C^2_{ga}} + A^2}{\frac{1}{\omega^2 C^2_{ga}} + \left(A + \frac{\mu r_g r_e}{r_a + r_e}\right)^2}}.$$

$$\sin\left\{\omega t + \tan^{-1} A\omega C_{ga} - \tan^{-1}\omega C_{ga}\right.$$

$$\left.\left(A + \frac{\mu r_g r_e}{r_a + r_e}\right)\right\}. \quad .. \quad .. \quad (45)$$

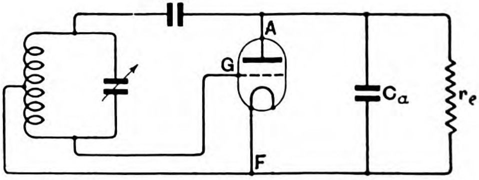


Fig. 15.—*Detector with neutrodyned input circuit to eliminate the feed-back and input load effects of anode-grid capacity.*

Inserting the value of A in (45), and writing

pr_a for r_e, and qr_a for r_g, the amplitude of the resultant grid voltage is

$$E_g = E\sqrt{\frac{\frac{1}{\omega^2 C^2_{ga}} + \left(q + \frac{p}{p+1}\right)^2 r_a^2}{\frac{1}{\omega^2 C^2_{ga}} + \left\{q + \frac{p}{p+1}\cdot\left(1+\mu q\right)\right\}^2 r_a^2}} \quad .. \quad .. \quad .. \quad .. \quad (46)$$

When r_e is much greater than r_a, so that $p/(p+1)$ can be taken as unity, and μ is large compared with unity, then approximately

$$E_g = \frac{E}{\sqrt{1 + \mu^2 r_g^2 \omega^2 C^2_{ga}}}. \quad .. \quad .. \quad (47)$$

If the amplifying stage under consideration is the second of two similar stages, r_g, will be about equal to r_a. If the stage immediately follows the detector, r_g, will be considerably greater owing to the high average internal resistance of the detector, and will be different for the two halves of the voltage wave. This difference will cause the production of even harmonics in the resultant grid voltage of the amplifier, and in μe_g.

To give an idea as to the order of magnitude of the effect of the feed-back on the amplitude of the input an average numerical case will be considered. As the feed-back is only appreciable at the higher audio frequencies, the effect at 10,000 cycles will be considered. Let r_a = 20,000 ohms, and μ = 30 for the amplifying valve. If the preceding stage is similar, r_g may be taken as 20,000. The relation between E_g/E and C_{ga} is given by curve *A* in Fig. 12.

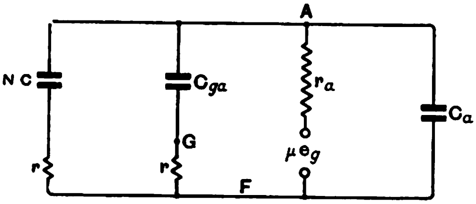


Fig. 16.—*Equivalent output circuit of neutrodyned detector.*

If the preceding stage is the detector, it may be assumed that during the positive half cycle the average value of the internal resistance (r'_a) is 100,000 ohms. Taking the detector external resistance (r'_e) = 250,000, and the amplifier leak resistance as 1 megohm, gives an effective input resistance r_g = 66,700 ohms. The corresponding relation between E_g/E and C_{ga} is given by curve *B*, Fig. 12.

For the negative half cycle of the same stage it may be assumed that r'_a is high compared with the external resistance and leak in parallel. Thus r_g will be about 200,000 ohms.

The corresponding relation between E_g/E and C_{ga} is shown by Curve *C*, Fig. 12.

In all cases the effect of the feed-back is to reduce the input. The reduction is not serious with the second L.F. stage (curve *A*), even at 10,000 cycles, if the anode-grid capacity does not exceed 10$\mu\mu F$. The effect is more serious in the first L.F. stage, and the large difference between curves *B* and *C* indicates the probability of considerable wave form distortion—the resultant grid voltage amplitude in the positive direction is nearly twice the negative amplitude with C_{ga} = 5$\mu\mu F$.

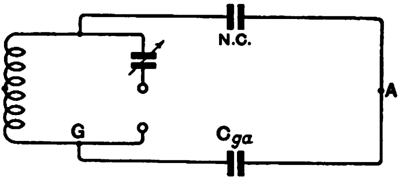


Fig. 17.—*Equivalent input circuit of neutrodyned detector.*

The effect of feed-back on the audio frequency characteristic is shown in Fig. 13 for a constant value of C_{ga} 10$\mu\mu F$. The curves *A*, *B*, and *C*, refer to the same conditions, respectively, as the curves in Fig. 12.

Frequency curves for other values of C_{ga} may be easily deduced from the curves in Fig. 13 by a change in the frequency scale. If C_{ga} has any value 10x$\mu\mu F$., the same curves will apply if the frequency scale is divided by x. Thus, if C_{ga} = 5$\mu\mu F$., then x = 0.5, and the frequency scale must be multiplied by 2.

In order to improve the performance of the first L.F. amplifying stage (represented by curves *B* and *C*, Fig. 13) it is evident from equation (47) that $\mu r_g \omega C_{ga}$ must be reduced to make the characteristics more level, and also the values of r_g for the positive and negative half cycles must be made more nearly equal to reduce wave form distortion.

The latter condition can be partially met by inserting a high resistance—say 100,000 ohms—between the grid leak and grid of the amplifying valve; but unfortunately, this increases the effective input resistance (r_g) for both half cycles and makes the characteristic less level than before. In other words, the effect of the series grid resistance is only to lower B (Fig. 13) more than C at the upper frequencies. As both curves B and C require raising at these frequencies, the series grid resistance has, on the whole, a harmful rather than a beneficial effect.

Alternatively, as ω and C_{ga} are outside control, the value of μ for the first L.F. valve may be reduced, and the leak resistance and external resistance in the anode circuit of the detector may be lowered. All these changes have the desired effect of raising both characteristics, and of raising C more than B. Suppose μ is reduced to 16, r'_a to 100,000 ohms, and r to 0.5 megohm. Then, for the positive half cycle, taking r'_a as 100,000 ohms as before, $r_g = 45{,}600$ ohms. For the reverse half-cycle $r_g = 83{,}300$ ohms (*i.e.*, the joint resistance of r'_a and r in parallel). The audio frequency characteristics for these new values, and $C_{ga} = 10\mu\mu F.$, are shown by the dotted curves D and E in Fig. 13. The improvement in the characteristic is obtained only, as usual, at the expense of signal strength which, in the case considered above, would be reduced to about a quarter of its original value.

However, the entire effect of the feed-back may be overcome, without loss of signal strength, by the adoption of a neutrodyned push-pull system, as shown later.

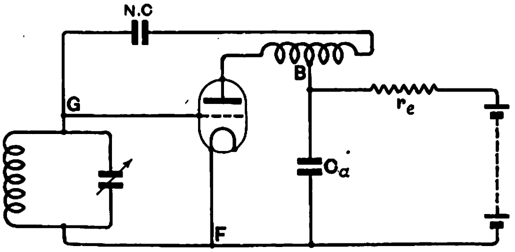


Fig. 18.—*Illustrating an ineffective anode circuit neutrodyne. Potential variations at B are fed back to the grid.*

Phase Shift of Audio Frequencies.—From equation (45) the angle of lag of the resultant grid voltage behind the original input voltage is given by

$$\phi = \tan^{-1} \omega C_{ga} r_a \left[\left(q + \frac{p}{p+1} \right) + \frac{\mu p q}{p+1} \right] - \tan^{-1} \omega C_{ga} r_a \left(q + \frac{p}{p+1} \right) \quad .. \ (48)$$

Assuming, as before, that $p/(p+1)$ can be taken as unity, and that μ is large compared with unity, the angle of lag reduces, approximately, to

$$\phi = \tan^{-1} \mu r_g \, \omega C_{ga} \quad .. \qquad .. \ (49)$$

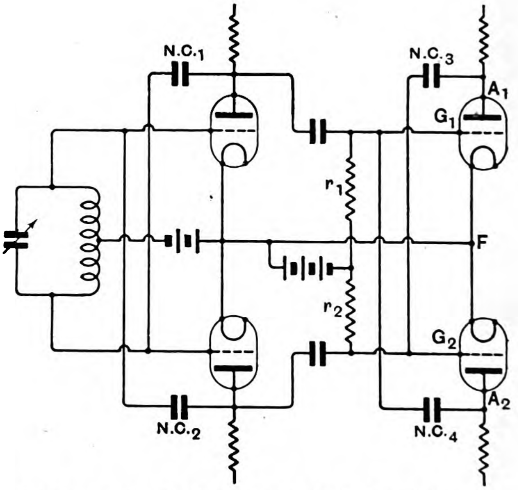


Fig. 19.—*Neutrodyned push-pull circuit for detector and R–C amplifier, to eliminate the effects of anode-grid capacity.*

The numerical relation between ϕ and the audio frequency is shown in Fig. 14. The curves A, B, and C, refer to exactly the same conditions as for the corresponding curves in Fig. 13. As the phase displacement of the resultant input varies considerably with the audio frequency, the shape of a complex wave form will be distorted by the feed-back action, the higher frequency components lagging behind their position in the original input wave.

Elimination of Feed-back Effect in Detector.—By employing a neutrodyne input circuit to the detector it is possible to cut out both the feed-back and the input load effect due to the anode-grid capacity. The connections are shown in Fig. 15. This circuit, from the point of view of the radio frequency voltage (μe_g) in the anode circuit is equivalent to that shown in Fig. 16. As μe_g sends current in opposite directions through the two halves of the input winding its inductance will be practically neutralised if the two sections are closely coupled and balanced. The impedance between grid and filament then reduces simply to the ohmic resistance (r) of the grid-filament section of the winding. As this resistance is negligible compared with the reactance of C_{ga}, the feed-back voltage between grid and filament will be negligible. This applies equally to all side band frequencies as there is no resonant circuit for μe_g to operate upon.

As regards the original input voltage the circuit is equivalent to that shown in Fig. 17. The capacity load on the input is that due to C_{ga} and NC in series. When the circuit is balanced there is no P.D. across r_a or r_a due to e (points F and A being at the same potential) so that their resistance loading effect is eliminated. This is true whatever may be the nature of the external load in the anode circuit.

By adjustment of NC the resultant voltage on the grid may be made to increase, keep constant, or to decrease, when the filament of the valve is switched on and μe_g comes into action.

It may be mentioned that it does not appear to be practicable to neutralise the effect of C_{ga} from the anode circuit, by any arrangement such as that shown in Fig. 18. In this scheme any variation of potential at the point B is fed back to G.

The divided input circuit of Fig. 15 is easily adaptable as a neutralised push-pull detector to be followed by resistance-capacity stages similarly arranged, as described later.

Elimination of Feed-back Effect in L.F. Amplifier.—The effects of the anode-grid capacity in a resistance-capacity coupled amplifier may be eliminated by the push-pull arrangement of Fig. 19, in which the connections for the detector and first L.F. amplifier are shown. An important feature of the arrangement is that the balance for the anode circuit E.M.F. of the amplifier is not disturbed at all by any inequality in the effective input resistances of the two L.F. valves, such as may be due to the use of leak resistances of unequal value or to the fact that the internal resistance of the detector valves is different for the positive and negative half-cycles. The reason for this will be clear from the equivalent circuit (for the anode circuit E.M.F.) of the amplifier given in Fig. 20, which is lettered to correspond with Fig. 19. If the capacities are balanced it is evident that the A.C. potentials of both G_1 and G_2 are equal to that of the mid-point of the total anode circuit E.M.F., *i.e.*, to that of the filament F. Hence μe_g can produce no current through the input resistance r_1 and r_2, whatever their values may be; and any point on them between G_1 and G_2 may be connected to F without affecting the balance.

As regards the input voltage applied across G_1, G_2 (Fig. 20), the anode potentials (A.C.) at A_1 and A_2 are the same, their value being that of the mid-point of $r_1 + r_2$. If F is joined to this mid-point no current from the input can flow through either r_a. Thus, in this case, the input load due to r_a (and also that due to the external load in the anode circuits of the amplifying valves) is cut out. This means that the leak resistances r_1 and r_2 must be equal to reduce the input loading effect to a minimum.

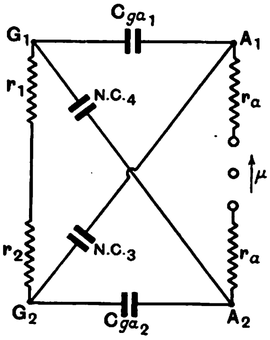


Fig. 20.—*Equivalent circuit of neutrodyned push-pull R–C amplifier.*

Evidently the same method of neutralising C_{ga} is applicable to push-pull transformer coupled L.F. stages.

The Final or Power Stage of Amplifiers.*

By Manfred von Ardenne.

In considering the final stages of an amplifier it is possible to start from very different hypotheses. If it is assumed that the voltage applied to the grid of the last valve is *small*, then it is known that the best conditions are complied with when the internal resistance of the output valve is made equal (by selection of a suitable amplification factor) to the resistance offered by the loud speaker to notes in the middle of audible range. If the preceding stage of voltage amplification can be assumed capable of delivering to the last valve alternating voltages which, within the range of frequencies considered, may be as large as desired without distortion, one arrives at a different result. Provided further that the output valve does not show saturation, or that saturation first makes its appearance in the region of positive grid voltages (as in Fig. 1), then the maximum output, as different authors† have deduced, is given *when the resistance in the anode circuit has double the value of the internal resistance of the valve.*

If full dynamic use is to be made of the valves, it becomes necessary to determine the operating voltages with which a given valve delivers the maximum output to a particular loud speaker. The last case is therefore of particular importance, for in practice the voltages are always easy to alter, while in most cases one has to make use of the valves and loud speaker available. The electrical output is dependent upon the magnitude of the alternating component of the anode current and the value of the resistance of the loud speaker through which this current flows. The maximum output is determined by the value of the greatest permissible current through the valve. The highest value of the alternating component of the anode current can be read off from the characteristic curve. In the case of the valve of which the characteristic curve is given as an example, in Figure 1, the anode current must not fall below the value $\overline{I_{p2}}$, nor rise above the value $\overline{I_{p1}}$, for only within the range between $\overline{I_{p1}}$ and $\overline{I_{p2}}$ is it permissible to regard the characteristic of this valve as a sufficient approximation to a straight line. The maximum alternating current is obtained when the working point is at the middle of the straight region, that is, at $\overline{I_p}$. The greatest value of the alternating anode current which can be delivered without distortion has the value

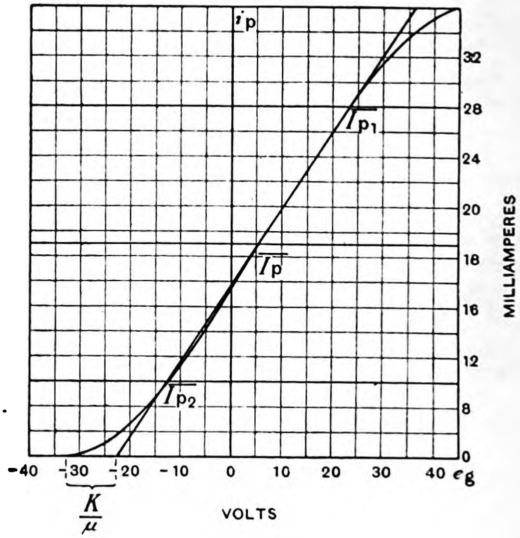


Fig. 1.

$$\tfrac{1}{2}(I_{p1} - I_{p2}) = I_p.$$

Whether this current can be delivered without distortion to the loud speaker at all relevant frequencies depends only upon the anode and grid voltages in use.

In order to avoid distortion it is not only necessary to ensure that the working point cannot travel out to the regions in which the characteristic is curved, but it is even more important to take care that the working-point always remains within the region of grid voltages to which there corresponds *zero grid current.* It is equally necessary to fulfil these two conditions for freedom from distortion when considering the working characteristic; that is, when examining the properties of valve and loud speaker as a single whole.

---

* The nomenclature employed in this paper corresponds to that given by E. L. Chaffee in his paper "Vacuum Tube Nomenclature," *Proc. I.R.E.*, March, 1927.

† W. F. Brown, *Proc. Phys. Soc.*, Vol. 36, III, 1924. W. P. Radt, "Ueber Maximalleistungen von Verstärkerröhren," *E.N.T.*, 1926, Part 3. J. C. Warner and A. V. Loughren, *Proc. I.R.E.*, Vol. 14, No. 6, 1926.

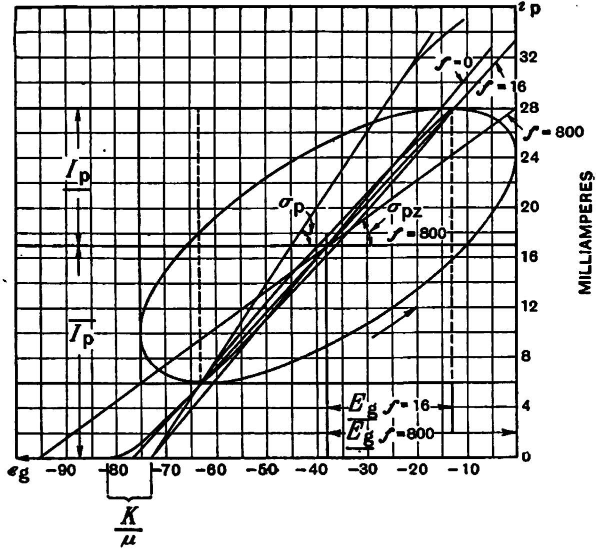


Fig. 2.

The load in the plate circuit of the output valve, if the usual inductive loud speaker is used, consists essentially of an inductance L and an effective resistance R_{bw}. The resistance can be resolved into the pure ohmic resistance of the bobbin windings and the resistance of operation R_w. The resistance of operation, which depends upon frequency, is in its turn made up of the loss-resistance R_{wv}, which is chiefly determined by the losses in the iron, and the *useful resistance* R_{wn} occasioned by the reaction of the moving parts of the loud speaker system. On account of the poor electro-acoustic efficiency of most loud speakers in use to-day the useful resistance R_{wn} is very small in comparison with all other resistances of the loud speaker. R_{wn} can therefore be neglected in many calculations. In cases where the useful resistance cannot be neglected, as for example in the investigation of the effect of frequency in the output stage, a mean value for R_{wn} will be assumed in later paragraphs. It is necessary to take a mean value, for with loud speakers of all types the useful resistance can vary over a wide range. In particular it increases for the frequencies for which the moving parts of the loud speaker come into resonance with the current energising it.

In order to obtain an insight into the dynamic relations holding in the output stage, the influence of the loading of the anode circuit occasioned by the loud speaker will now be examined. In the case of a purely ohmic anode resistance the dynamic characteristic, or the working characteristic which can be deduced from the familiar relations of resistance amplification, is practically a straight line, the slope of which is given by the following expression:

$$\sigma_{p\,r} = \frac{\sigma_p}{1 + \frac{R_b}{r_p}} \quad \ldots \quad \ldots \quad (1)$$

As soon as the load in the anode circuit ceases to be a pure resistance but has in addition an inductive or capacitative component, a phase-displacement between the grid voltage E_g and the anode current $\underline{I_p}$ of the valve makes its appearance. The characteristic then becomes an ellipse, which is elongated more or less according to the ratio of the imaginary to the real component. The ellipse can be constructed graphically, or accurately calculated.‡ In Figure 2 ellipses have been calculated for two different frequencies under the conditions given. From the ellipses the phase-displacement between the anode current and the grid voltage can be deduced. When the grid voltage is at its maximum or minimum, then the anode current, in the case of the inductive load here considered, attains its maximum or its minimum; that is, the ellipse is traversed in a counter-clockwise direction. In the majority of cases it is not necessary to know the exact path of the ellipse which is the real working characteristic; it is almost always sufficient to know the diagonal of the rectangle which encloses the ellipse. The slope of this diagonal, which we can use as an ideal working characteristic, expressed in terms of the lengths of the sides of the rectangle, is in the general case:

---

‡ See Manfred von Ardenne, "Zur Theorie der Endverstärkung," *Jahrb. d. drahtl. Telegraphie u, Telefonie*, Vol. 30, Part 4. Manfred von Ardenne, "On the Theory of Power Amplification," *Proc. I.R.E.*, 1928. L. Müller and M. von Ardenne, "Die Transformatorenverstärker," published by R. C. Schmidt, Berlin.

$$\sigma_{pz} = \frac{I_p}{\underline{E_g}} = \frac{\mu}{Z_B} \quad .. \quad .. \quad (2)$$

and in the case of inductive loud-speakers with small self-capacity this becomes:

$$\sigma_{pz} = \frac{\mu}{\sqrt{(\omega L)^2 + (r_p + R_{bw})^2}} \quad .. \quad (2a)$$

It follows from this that for an inductive loud speaker the slope decreases with rising frequency, and with decreasing frequency approaches the limiting value

$$\frac{\mu}{R_{bw} + r_p} \approx \frac{\mu}{r_p + R_b} = \sigma_{pr} \quad .. \quad (3)$$

determined by the resistances, R_b and r_p.

On the basis of the conditions for freedom from distortion that have already been mentioned, the following reasoning can be applied to the rectangle. The top and bottom sides of the rectangle are given by the two values $\overline{I_{p1}}$ and $\overline{I_{p2}}$ of the current, provided that the straight portion of the static curve extends over the region between these two values. If it is assumed that no appreciable grid current flows until zero grid voltage is reached, we know also that the grid voltage may not travel to the right of the vertical axis; that is, the vertical axis itself forms the third side of the rectangle. We can regard as a critical rectangle for distortionless working the rectangle having sides of lengths $(\overline{I_{p1}} - \overline{I_{p2}})$ and $2\overline{E_c}$, so that one corner is given by the point $e_g = 0$, $i_p = \overline{I_{p1}}$. Then $\overline{I_{p1}} = i_{p\max}$ and $\overline{I_{p2}} = i_{p\min}$, so that $(\overline{I_{p1}} - \overline{I_{p2}}) = 2\underline{I_p}$, and further $2\overline{E_c} = 2\ \underline{E_g}$. These relationships can be clearly seen by referring to the diagram of Figure 3. So long as the working ellipses for all frequencies within the audible range lie within this rectangle, there will be no distortion. The conditions for operating the valve outside the regions of curvature of the characteristic on the one hand, and grid current on the other, can therefore be formulated in the following manner:

In order that a given valve may deliver to a given loud speaker a maximum undistorted output, the anode voltage must be so chosen that the ideal characteristic (diagonal of the rectangle) for a critical frequency goes through a point having the co-ordinates $e_g = 0$, $i_p = \overline{I_{p1}} = \overline{I_p} + \underline{I_p}$. From this statement and from certain elementary mathematical deductions it follows that the necessary voltage for the anode-current source is given by the general formula:

$$\overline{E_B} = K + \overline{I_p}(r_p + R_b) + \underline{I_p} Z_B \quad .. \quad (4)$$

In this equation K represents a voltage-correction which can easily be read off from the characteristic of the valve, and which is inserted in order to make possible the use of a linear relation for the anode current. Z_B, which also enters into equation (2) represents the absolute total of all

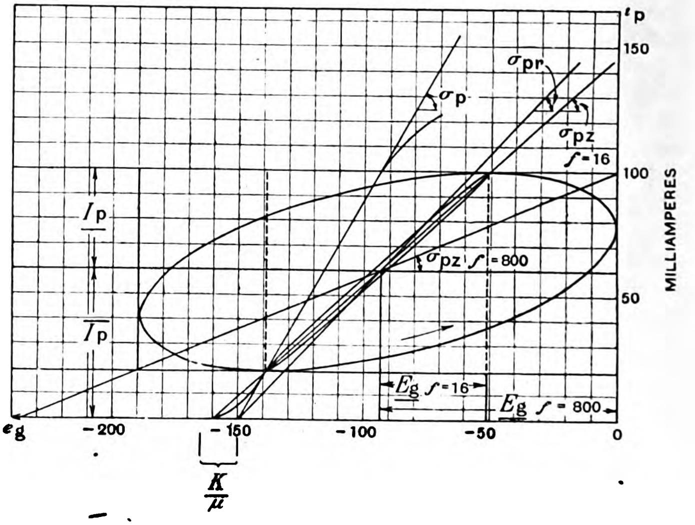


Fig. 3.

resistances in the valve circuit. Equation (4), in the case of an inductive loud speaker becomes:

$$E_B = K + \overline{I}_p(r_p + R_b) + \underline{I_p}\sqrt{(\omega L)^2 + (r_p + R_{bw})^2} \quad .. \quad (4a)$$

This expression gives us, to repeat it once more, the minimum value of voltage necessary for the anode current supply in order to make full use of the output valve, in conjunction with a given loud speaker. Expressed in words the formula, which is exceptionally easy to understand and can be grasped at a glance, states that *the voltage of the anode-current supply must be at least high enough to cover, in addition to the voltage-correction K, both the D.C. voltage-drop in the ohmic resistances r_p and R_b, and the A.C. voltage-drop in the impedance Z_B made up of r_p and Z_b.* As can be seen from the physical relationships mentioned, which find their expression in the formula given, the voltage of the anode-current supply must be greater, in the case of inductive loud speakers, the higher the frequency that is adopted for purposes of calculation. If, for the calculation of the anode voltage, we assume a frequency of 10,000 cycles, which lies at the upper limit of the audible range, and put ω equal to 63,000, we shall obtain from the usual data very high values for the anode voltage.

In practice, however, it is desirable to base the calculation, whether for music or speech, on a very considerably lower frequency, for in both the greatest sound intensities are to be found about the middle of the audible range. It follows therefore that the greatest signal voltages which are applied to the grid of the output valve, and are liable to cause overloading, are of medium frequency. On the basis of measurements which have been made during operation, it can be stated definitely that in both music and speech the amplitude of the signal voltages of a frequency higher than 800 cycles falls away more rapidly than does the slope of the ideal working characteristic. In considering inductive loud speakers we can therefore take 800 cycles as the *critical frequency* for the purpose of choosing the anode voltage. Quite different relationships apply in the case of an inductive loud speaker with a parallel capacity, or of a capacitative speaker with choke-feed, where the valve circuit contains both inductance and capacity. These form an oscillatory circuit, for the resonance frequency of which the impedance to alternating currents attains its highest value. The resonance frequency must, then, be taken as the critical frequency for the purpose of calculation, provided that it does not lie at a frequency above 800 cycles.

From equation (4), with the assistance of the relation

$$\overline{E_c} = \frac{\overline{I_p}}{\sigma_{pr}} - \frac{E_B - K}{\mu} \quad .. \quad (5)$$

we obtain the following expression for the grid-bias required:

$$\overline{E_c} = -\frac{\underline{I_p}}{\mu} \cdot Z_B \quad .. \quad .. \quad (6)$$

The equation for the grid-bias shows that the amplitude of the signal voltage must never exceed the value

$$\underline{E_g} = \frac{\underline{I_p}}{\mu} \cdot Z_b \quad .. \quad .. \quad (7)$$

Care must be taken here that the frequency taken as critical for the purpose of choosing the anode voltage is not inserted into this expression without some consideration. As can be seen, for example, in Figure 2, the narrow working ellipse corresponding to a low frequency will extend upwards and downwards into the region within which the characteristic is curved if a signal voltage of low frequency and of amplitude greater than that calculated from equation (7) for this frequency is applied to the grid of the output valve. It follows that for inductive loud speakers the limiting value for the signal voltage must be calculated for the lowest frequency that needs to be taken into consideration. With present-day transmitting and reproducing apparatus it is in most cases sufficient to take 50 cycles for this purpose. When the last valve has both capacity and inductance in its plate circuit, it is not possible to state generally whether the lowest value of permissible signal voltage corresponds to the upper or lower critical frequency, for this will depend on the position of the resonance frequency between the two critical frequencies. There have been calculated in Figures 2 and 3 for two output valves the anode voltages necessary in order that a maximum undistorted alternating current output may be delivered to a loud speaker having the properties there shown. In order to make full use of the valve shown in Figure 2, in conjunction with the loud speaker suggested, which is typical of the average commercial instrument, the calculation gives 374 volts as the necessary anode voltage. For the valve of Figure 3 the corresponding anode voltage is 927 volts. The grid-bias and the alternating grid voltages corresponding to the two critical frequencies can be read off from the two Figures. Both diagrams show clearly the flattening of the working characteristic by the ohmic component of the resistance in the anode circuit. As can clearly be seen from Equation (4) which gives the anode voltage necessary, the voltage of the anode current supply must be increased by the amount of the voltage-drop $I_p . R_b$ across the ohmic component of the impedance in the anode-circuit. The ohmic resistance of the loud speaker is generally given, and in any case can only be brought with difficulty below a certain value if an adequately large useful resistance is required. In order to avoid this difficulty without being compelled to employ an unnecessarily high anode voltage, the well-known choke-feed can be employed; in this case the direct current passes through a choke with low ohmic resistance and high inductance, while the signal current passes through a suitable large condenser and the loud speaker. The employment of choke-feed in the output stage is not only helpful in reducing the value of the anode voltage necessary, but in the case of all modern loud speakers in which polarisation by a steady current is undesirable, it is absolutely necessary.

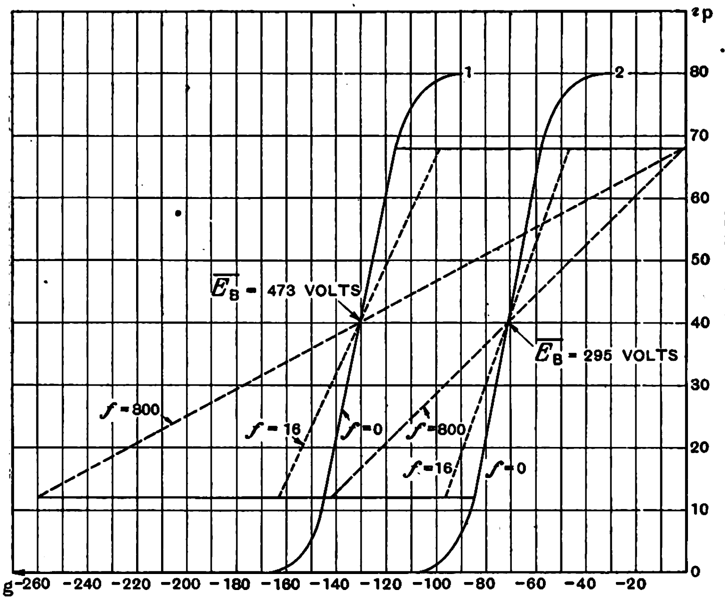


Fig. 4.

In considering the output stages and the characteristics which follow, the adoption of choke-feed, using a choke of negligible resistance, is assumed.

With the aid of the formula for the necessary voltage of the anode-current supply quite a number of other interesting questions concerning the output stage can be answered. If, in place of a single loud speaker, the output valve is made to supply two identical loud speakers in parallel, and if we assume that this change leaves the steady plate current and the maximum alternating current in the anode circuit unaltered (which is true if choke-feed is in use), then each loud speaker will carry a current half as great as that which would flow through a single speaker. The output wattage, in the case of one loud speaker, is given by:

$$W_o = R_{wn} \frac{I_p^2}{2} \quad .. \quad .. \quad (8)$$

By connecting two loud speakers in parallel the *total* current will not be changed. The useful resistance, however, will be reduced to half its previous value on account of the parallel connection.

$$\frac{R_{wn}}{2} . \frac{I_p^2}{2} = \frac{W_o}{2} \quad .. \quad .. \quad (8a)$$

It follows from this that the output wattage attainable with a valve is reduced by connecting two speakers in parallel to half the value that can be reached with one loud speaker only. At the same time, however, as can be seen from Equations (4a), (6) and (7), the anode voltage and grid-bias necessary, together with the signal voltage required to load the valve fully, are all reduced. In order to present these relationships more clearly, there have been calculated in Figure 4 the characteristics and the necessary (optimum) working voltages both for one loud speaker, and for two connected in parallel. With the valve used here (actually two identical valves connected in parallel), and with the given data for the loud speaker, the anode voltage necessary for a *single* loud speaker comes out as 473 volts, while for two connected in parallel the anode voltage is reduced to 295 volts.

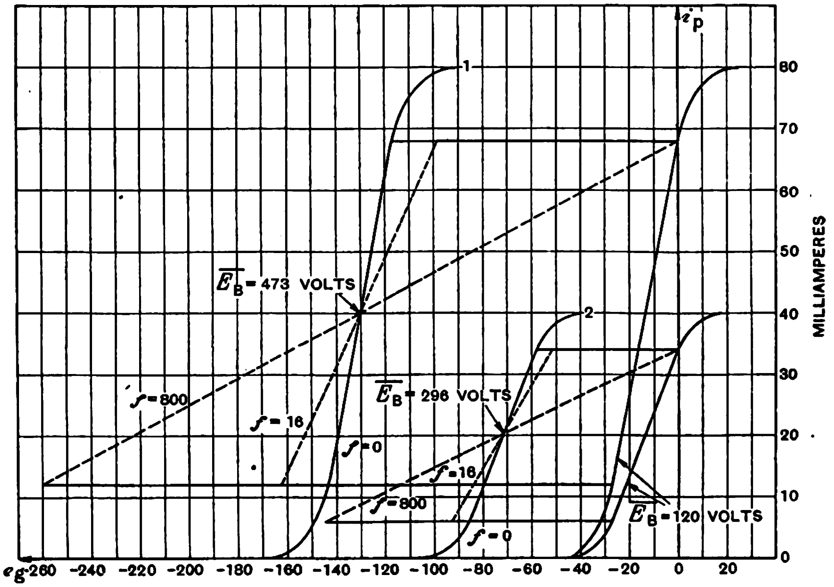


Fig. 5.

The next point to consider after the parallel connection of loud speakers is the effect of connecting them in series. Several loud speakers connected in series cause an increase of the resistance in the plate circuit of the output valve, and therefore involve an increase in the anode voltage, as can immediately be calculated from Equation (4). If the anode voltage, the grid-bias, and the signal voltage applied to the grid are all increased to the extent demanded by Equations (4a), (6) and (7), the output, for *n* loud speakers connected in series, is increased *n* times, for

$$nR_{wn} \cdot \frac{\underline{I_p}^2}{2} = nW_o \quad \ldots \quad \ldots \quad (8b)$$

From this it follows that the output wattage obtainable from very small valves can be increased if the resistance in the anode circuit is raised and the anode and grid voltages are increased to correspond. On account of the danger of high voltages and of the fact that the usual output valves will only stand with safety a certain voltage, dependent for its exact value on the type of valve employed, this method for increasing the output is not in general to be recommended.

Rather is it desirable to endeavour to obtain the required high output with *low anode voltages.* Small output valves require proportionately low anode voltages, when they are used in conjunction with a given loud speaker. But as soon as several small valves are connected in parallel in the endeavour to obtain high outputs, higher anode voltages are again necessary. This is shown clearly by Equations (4) and (4a). If *n* small valves are connected in parallel, the necessary voltage of the anode-current supply becomes:

$$\overline{E}_B = K + {}_n\overline{I}_p\left(\frac{r_p}{n} + R_b\right) + n\underline{I_p}\sqrt{(\omega L)^2 + \left(\frac{r_p}{n} + R_{bw}\right)^2} \quad \ldots (4b)$$

The various characteristics for *a single valve* and *for two valves connected in parallel,* the valves being of a modern output type, are given in Figure 5. If it were possible to neglect the effect of the resistance in the plate circuit on the characteristics, or if this resistance were small compared with the internal resistance of the valve for all frequencies within the audible range, then an anode voltage of 120 volts would be sufficient, for valves of this type, to permit of making full use of the valve. If a single valve is used in conjunction with a loud speaker of which the ohmic resistance can be neglected (compare in this connection the remarks already made), and of which the remaining data are given in Figure 5, an anode voltage of 296 volts is necessary. The corresponding grid voltages can be found from Figure 5. So long as it is only required to listen in an ordinary living-room, and no very great sound intensity is needed, an output stage with a valve such as is given in Figure 5 is quite sufficient. If it is desired to deliver still greater undistorted alternating-current power to the loud speaker, two valves of the same type can be connected in parallel. The anode voltage required then rises considerably, amounting, in the example given in Figure 5, to 473 volts. The two valves connected in parallel then behave exactly like a single valve of correspondingly greater size. We know therefore that it is not possible, *with low anode voltages*, to obtain a higher maximum output by connecting valves in parallel. By connecting n valves in parallel the anode output itself increases n^2 times, provided that the working voltages are increased in accordance with the equations given.

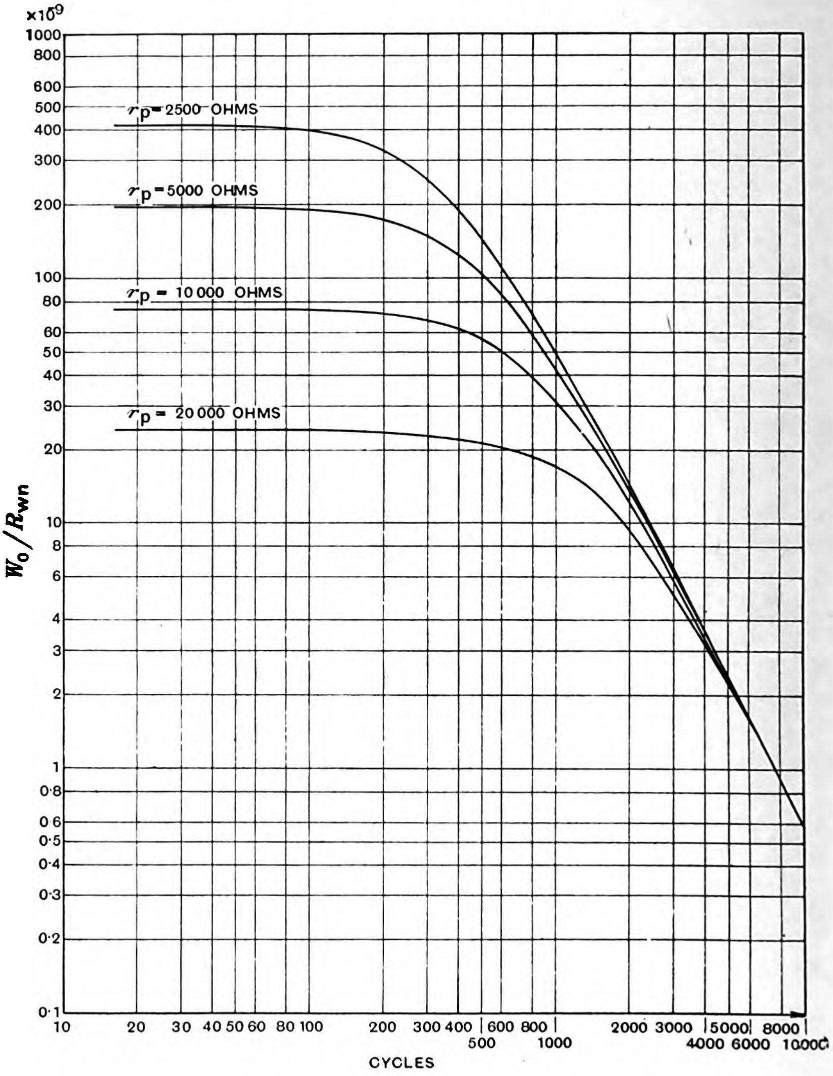


Fig. 6.

$$R_{wn} \,.\, \frac{(nI_p)^2}{2} = n^2 W_o \qquad .. \text{ (8c)}$$

In this connection the comparison of the anode output from an output stage consisting of a single valve and a single loud speaker, and that from an output stage consisting of two valves in parallel feeding two loud speakers also connected in parallel is of especial interest. As can be seen by a comparison of Curve 2 of Figure 4, which corresponds to two valves in parallel supplying two loud speakers in parallel, with Curve 2 of Figure 5, which is based on only *one* valve and *one* loud speaker, the working voltages correspond closely in the two cases, and the output wattage for *n* loud speakers in parallel, and *n* valves in parallel is

$$\frac{R_{wn}}{n} \cdot \frac{(nI_p)^2}{2} = nW_o \qquad \ldots (8d)$$

The output wattage is thus *n* times that from a single loud speaker (Equation 8). The example shows that by connecting in parallel a number of identical valves, and by connecting in parallel a corresponding number of loud speakers (or by employing a loud speaker of lower resistance) it is possible to increase the output wattage, and with it the output of sound, without the necessity for raising the voltages on grid and anode.

In this connection attention may be drawn to a few points connected with the construction and choice of output valves. From the equations given in this article can be deduced the following general statement, which is also immediately obvious. *The necessary voltage for the anode-current supply can be decreased, and the alternating-current power delivered to the loud speaker can be increased, by choosing a smaller value for the internal resistance of the output valve.*

The internal resistance of a valve can, as is well known, be lowered by lowering the amplification factor. In the output stage, where we are in most cases not greatly concerned with the voltage-amplification, we can employ values of μ as small as 2½. If so small a value of μ is used we must of course increase proportionately the signal voltage applied to the grid, and must therefore choose suitable values for the voltage-amplifying stage that precedes. If we insert into the equation for the output wattage (8) the relation for the alternating anode current, we arrive at the following expression:

$$W_o = \tfrac{1}{2} R_{wn} \cdot \mu^2 \cdot \underline{E}_g^2 \cdot \frac{1}{Z_B^2} \qquad \ldots (9)$$

which, for the case of an inductive loud speaker, becomes:

$$W_o = \tfrac{1}{2} R_{wn} \, \mu^2 \, \underline{E}_g^2 \cdot \frac{1}{(\omega L)^2 + (r_p + R_{bw})^2} \qquad (9a)$$

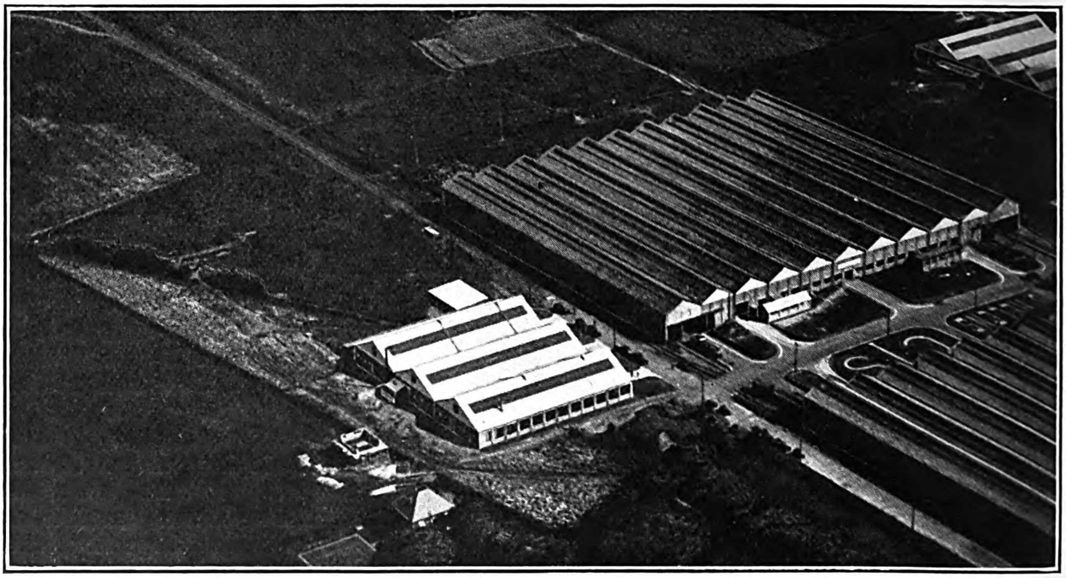
The equation shows that $\underline{E}_g$ must be increased or diminished in proportion to $\frac{1}{\mu}$ if it is required to keep the output wattage constant. From Equation (9a) for the output wattage with an inductive loud speaker there follows further the dependence of the output wattage upon the frequency, which will now be considered.

The dependence upon frequency of the output wattage, or rather of the ratio $\frac{W_o}{R_{wn}}$ for $\underline{E}_g = 1$ volt, and the values for loud speaker and valve characteristics there shown is given in Figure 6 for several values of the internal resistance of the valve. The slope of the curve at the higher frequencies corresponds approximately to a decrease of the output according to the second power of the frequency. We know that the variations with frequency in the output stage are extraordinarily large, and of quite a different order of magnitude to those obtaining in the voltage-amplifying stages, even if we remember that a decrease of voltage in the voltage-amplifying stages to $\frac{1}{n}$th corresponds in the output stage to a decrease of output in the ratio of $\frac{1}{n^2}$.

It has already been pointed out above that R_{wn} is not constant, but increases, as a very rough approximation, as the second power of the frequency. We therefore obtain in the region of the higher frequencies an approximately constant sound-pressure for equal voltages on the grid of the output valve. At low frequencies, on the other hand, owing to the dependence of R_{wn} on frequency, the strength of sound becomes less. The curves of Figure 6 show that *the low notes are better reproduced as the internal resistance of the output valve is reduced.* For this reason also a low valve-resistance in the output stage is important. When it is said that the useful resistance increases as the second power of the frequency, this statement is only intended to be very approximate. In spite of the fact that with commercial loud speakers the values for the inductance and the ohmic resistance of the windings do not depart greatly from one another, the R_{wn}-curves diverge so widely that it is not possible to give any general best value for r_p from the point of view of dependence on frequency. Good reproduction of the lower notes, without unfavourably affecting the higher notes, is obtained from the usual loud speaker when it is used in conjunction with valves having an internal resistance of from one to two thousand ohms. In order to obtain in the output stage as little variation as possible with frequencies within the audible range, it would be possible to use in the output stage two valves, one with a very high and the other with a very low internal resistance, each of them independently working its own loud speaker.

A new output valve that was recently being developed in the Philips Laboratory seems to contradict the points of view put forward in the present article. This valve, which is of the screened-grid type, has an amplification factor of about 100 and an internal resistance of about 60,000 ohms. If this valve is used in conjunction with a loud speaker having the usual characteristics, then for the lower frequencies, and for the middle frequencies of the audible range (*i.e.*, for frequencies below 800 cycles) the internal resistance of the valve is very much greater than the resistance in the anode circuit. As a result, the working characteristics will deviate but little from the static characteristics of the valve with comparatively low anode and auxiliary grid voltages, for in spite of its high internal resistance it possesses a slope of over 1mA/V over a wide range of anode currents.

On account of the high internal resistance the electrical effect of frequency, if the usual type of inductive loud speaker is in use, will be small, as can be seen from the formulæ given and from Figure 6. With regard to the dependence upon frequency of the useful resistance, the high frequencies will on this account be very well reproduced, while middle and low frequencies will be poor in comparison. The valve is however so constructed, in order that there may be the possibility of reproducing the low notes with it, that by connecting the screening-grid and the anode there results an output valve having an amplification factor of about 5 and a low internal resistance.



An aerial view of the new works of Graham Amplion, Ltd., at Slough. The offices of the administrative staff are on the left, whilst the buildings on the right comprise the factory.

On the Application of Condensers to the Measurement of Large Radio-frequency Currents.

By Philip R. Coursey, B.Sc., M.I.E.E.

FROM the earliest production of radio-frequency currents of any considerable magnitude—whether by the earlier damped-wave methods, or by the more modern C.W. apparatus—the measurement of such currents has presented a problem for which several solutions have from time to time been offered. The most important of these solutions so far utilised are as follows :—

(1) Hot-wire expansion type instruments giving direct deflectional readings on a graduated scale.

(2) The thermocouple type of instrument with appropriately constructed or shunted heater element.

(3) Transformer-coupled instruments with or without iron-core for the transformer, and utilising as indicator an instrument constructed in accordance with (1) or (2) above.

To these must now be added a method which has recently been developed into a practical form :—

(4) Condenser-shunt instruments, utilising as indicator a low-range meter constructed in accordance with (2) above.

In addition to these main methods, a considerable number of special instruments have been suggested, or used, from time to time, utilising other forms of construction or indication, but these have found no practical applications on any extended scale. It is the main purpose of this article to deal with the fourth class referred to above, and to indicate its sphere of utility in comparison with the other and better known arrangements.

The first method is perhaps the oldest as far as practical utilisation is concerned, since indicating ammeters utilising the expansion of a wire heated by the current were in use for industrial electrical measurements before any extended utilisation and measurement of radio frequency currents was required. While such instruments are practicable, even for large currents, for low- and for audio-frequencies, they are not practicable with any degree of accuracy for radio-frequency currents above about 10 amperes. For larger currents it is customary for low-frequency circuits to shunt the instrument, but such a method usually gives very inaccurate readings in radio-frequency circuits owing to the important part that the inductance of the parts of the circuit inside the instrument plays in determining the subdivision of the current between the shunt and the heater wire of the instrument. With such instruments the only way to ensure more consistent subdivision of the current through the meter is to construct the expansion element of a number of exactly similar strands of thin wire, all connected in parallel, one of the wires being used to operate the index. Such an arrangement is however, bulky and inconvenient. Somewhat similar disadvantages are attendant upon the construction of heavy current instruments of the second class, in order to ensure absolutely uniform subdivision of the current between the multiple wires of the heater. The disadvantage is, however, less serious in this case, since the heater and thermocouple elements of the meter can be located at some little distance, if necessary, from the indicating instrument used with them. A not inconsiderable expenditure of energy is moreover often called for in the heater element when the currents are large.

The transformer-coupled radio-frequency ammeter is a very satisfactory apparatus for the medium radio frequencies, but presents an increasing difficulty of construction for the higher frequencies called for in modern short-wave transmission. Whether the transformer has air or an iron core, errors creep in due to capacity currents and eddy currents in the conductors of the transformer, both of which become more serious as the frequency is raised. With iron-cored transformers the iron losses also increase with frequency and serious over-heating may arise unless very great care is taken in the design.

With the fourth method, tabulated above, making use of electrostatic condensers, these difficulties are not encountered, since on account of the decreasing impedance of a condenser as the frequency is raised, no excessive energy losses are found, and the method readily lends itself to accurate measurements at the highest frequencies.

The general principle of the arrangement, which is the invention of one of the Dubilier engineers, is depicted diagrammatically in Fig. 1*. Between the main instrument terminals T_1, T_2, two condensers C_1, C_2 are connected in parallel. One of these C_1 is given a capacity value very much larger than the other. In accordance with the well-known formula $I = C\omega V$, the total current flowing through the instrument divides in proportion to the capacity values of the two condensers. In practice, the ratio between the two capacity values is arranged to be a definite predetermined integral quantity, so that the large condenser shunts off a predetermined fraction of the total current, leaving the balance only to produce an indication on the low reading radio-frequency ammeter A. Ratios of 99 : 1 or 199 : 1 are convenient values, giving shunt powers of 100 and 200 respectively. The ammeter A used with this arrangement may be any one of the three types mentioned at the beginning of this article, but for preference is of the second or thermocouple type. Low direct-reading pointer instruments of this type can be used with these condenser shunts, and ammeters of this type in the lower ranges up to about 1 ampere are very accurate over a wide range of frequencies.

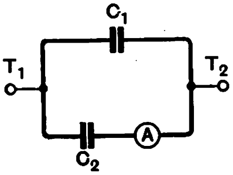


Fig. 1.

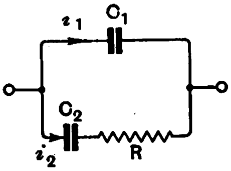


Fig. 2.

The accuracy of the complete meter incorporating these condenser shunts and the thermocouple indicating meter is necessarily limited to the accuracy of calibration of that meter, but with proper design satisfactory measurements of large currents at frequencies up to at least 60,000 kc. can be obtained. For still higher frequencies special ammeters of this type can also be designed to retain high accuracy of reading. An additional advantage of the thermocouple type of indicating meter as compared with the hot-wire type is that in the former case the actual indicator portion of the ammeter can be located at a distance from the main circuit. This is referred to more in detail below. The complete arrangement of an ammeter of this type incorporating the condenser shunts is theoretically subject to an error due to the resistance of the indicating meter. In Fig. 2, if C_1 and C_2 are the capacities of the two condensers and R is the resistance of the thermocouple the currents flowing through the two branches of the meter will be as follows :—

$$i_1 = C_1\omega v \qquad i_2 = \frac{v}{\sqrt{R^2 + \frac{1}{\omega^2 C_2^2}}}$$

If the meter had no resistance, that is $R = 0$, the current in the second branch would be $i_2' = C_2\omega v$. The effect of the resistance is to reduce the current flowing in the second branch of the shunt by an amount equal to

$$i_2' - i_2 = C_2\omega v - \frac{v}{\sqrt{R^2 + \frac{1}{\omega^2 C_2^2}}}$$

The indicating meter A Fig 1, will therefore read low by this amount, and expressing this as a fraction of the correct reading the error becomes

$$100 \times \left(1 - \frac{1}{C_2\omega\sqrt{R^2 + \frac{1}{\omega^2 C_2^2}}}\right) \text{ per cent.}$$

$$= 100 \times \left(1 - \frac{1}{\sqrt{R^2\omega^2 C_2^2 + 1}}\right) \text{ per cent.}$$

Taking values of C_1 and C_2, which are commonly adopted for a condenser shunt of this type for reading radio-frequency currents up to about 50 amperes, the meter is normally given a ratio of about 200 : 1, in which case $C_1 = 0.2\mu\text{F}$ and $C_2 = 0.001\mu\text{F}$. With this arrangement a thermo-junction ammeter reading up to 0.25 ampere will be used and an indicating meter of this type would normally have a resistance of about 2.6 ohms. Taking this figure and substituting in the above for the error, it is found that for a frequency of 6,000 kc. (which is a wavelength of 50 metres) the error in the ammeter reading becomes

---

* *British Patent*, 259,533. See also A. Nyman, *Proc. Inst. Radio Engineers*, February, 1928.

$$100\left(1-\frac{1}{\sqrt{(2.6)^2\times 36\times 10^{12}\times 4\pi^2\times (10^{-8})^2\times 10^{-12}+1}}\right)$$
$$= 0.5 \text{ per cent.}$$

If these particular values were used in a condenser shunt ammeter for frequencies up to 60,000 kc., the error would still be less than 5 per cent., which considering the high frequency is not very serious. For frequencies of this order and still higher capacities of lower value would be used so as to reduce the percentage of error in the readings.

The only source of error of any seriousness actually found in the use of meters of this type arises from the fact that the two condensers C_1 and C_2 and the thermo-couple A form a closed circuit which necessarily has some resonant frequency when the meter is used in short wavelength circuits and it occasionally happens that this resonant frequency comes within the range of a definite harmonic of the frequency of the currents passing through the meter, and in such cases a considerable irregularity in the meter readings is observed. It has been found that an effective method of overcoming this source of error is to absorb the energy of any circulating currents of this type by means of a small auxiliary circuit included in the main meter casing and itself tuned to the resonant frequency of the main loop in the meter. This absorbing circuit is connected to the meter circuit immediately adjacent to the thermo-ammeter as shown in Fig. 3, and then serves to absorb the power of the harmonic. This local tuned circuit is connected to the meter at one point only and in consequence its effect at all other frequencies than the resonant frequency is entirely negligible.

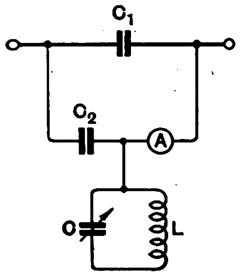


Fig. 3.

With this arrangement it should be noted that a meter of this type probably constitutes the most accurate standard known for the measurement of high-frequency currents. Apart from it, the only fundamental method of measuring such currents is a thermal method, involving the measurement of the heating due to the high-frequency current flowing through a known resistance, but this method is liable first to inaccuracy arising from the slight uncertainty of the value of the "known resistance" at high frequencies, and secondly to unknown shunting effects due to stray capacities between the heating elements and the calorimeter apparatus in which the measurements are carried out. With the condenser-shunt radio-frequency ammeter, errors due to stray capacities become entirely negligible, since the capacity values of the condensers in the ammeter are so much in excess of any stray capacities. A possible source of error may arise if the capacity values of the condensers used in the meter do not remain constant, but with properly constructed mica dielectric condensers the

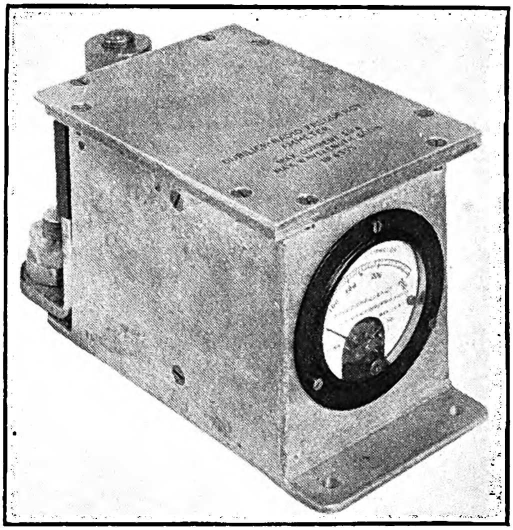


Fig. 4.

constancy is of a high order and practically independent of the frequency.

Fig. 4 illustrates an ammeter of this type, constructed with the condenser shunts included in a metal case to which is fitted a Weston thermo-junction milliammeter having a full scale reading of 250 milliamperes, thus giving, with a condenser shunt of 200 : 1, a range up to 50 amperes in the main circuit. As may be seen in the photograph the meter is provided with two substantial terminals for the main current connections, one of these terminals being mounted directly upon the case of the instrument and the second on an insulated conductor leading through to the condensers in the interior. The particular ammeter illustrated is constructed with capacity values of 0.199μF and 0.001μF, so that the smaller condenser has a value of exactly 1/200th of the total capacity in the ammeter.

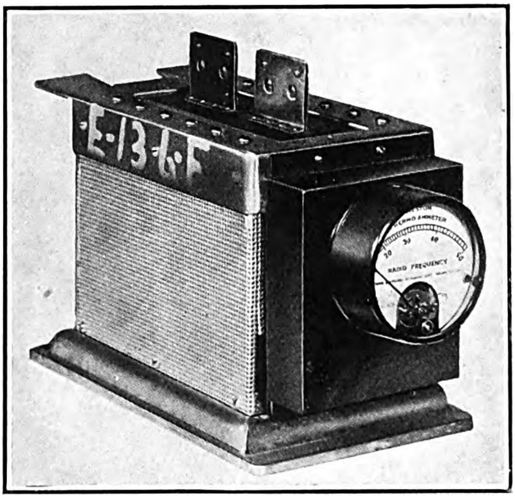


Fig. 5.

Since the passage of radio-frequency current through the meter gives rise to a volt drop across the terminals of the condenser which will increase with increase of wavelength of these currents, there is evidently a maximum wavelength (or minimum frequency) for which the meter is suitable without causing excessive stress in the dielectric of the condenser. By increasing the bulk of dielectric in the condenser for a given capacity value, the meter could be used for lower-frequency currents, but if this were done the volt·drop would tend to become excessive, and a more practical solution would be to use condensers of larger capacity values in the meter. Such an arrangement would, however, increase the cost of the meter and render it excessive as compared with the other types of radio-frequency meter already mentioned. Essentially, therefore, this type of ammeter is most suited for higher frequency currents. The particular meter, illustrated in Fig. 4, is suitable for wavelengths less than 500 metres, the useful range of frequencies for this meter, therefore, being about 10–500 metres (600 to 30,000 kc.).

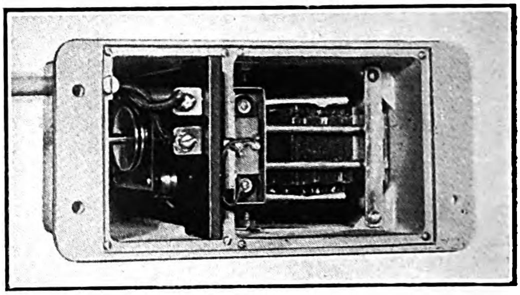


Fig. 6.

In the construction of the experimental model meter, illustrated in Fig. 4, a thermo-ammeter calibrated to 250 milliamperes was used. In practice, of course, in constructing meters of this type, the thermo-ammeter would be fitted with a false scale so as to read the true values of the main

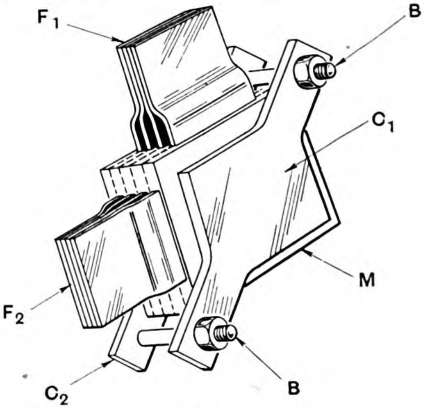


Fig. 7.

current correctly. Such an instrument is illustrated in Fig. 5, this one again having a maximum current-carrying capacity of 50 amperes, but provided in this case with two terminals both insulated from the container in which the whole apparatus is mounted as well as a common terminal connected to the metal case. These two insulated terminals enable the instrument to be used with two current ranges as is explained below.

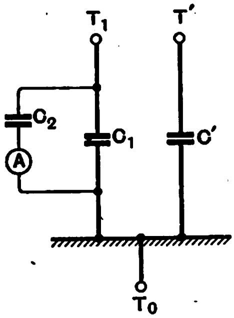


Fig. 8.

The tuned circuit to which reference has been made for absorbing the energy of stray harmonics is preferably constructed with a small fixed inductance used with a small adjustable capacity condenser so that the resonant frequency of this circuit can be adjusted to the required value after the meter has been constructed. A small parallel plate variable condenser provided with an adjusting screw which can be moved from outside the meter case is convenient for this adjustment. Such an arrangement is illustrated in Fig. 6, which is an inside view of the condenser shunt for one of these meters, the actual indicator in this instance being arranged at the end of two twisted leads enclosed in a metal tube leading away some distance from the condenser shunt.

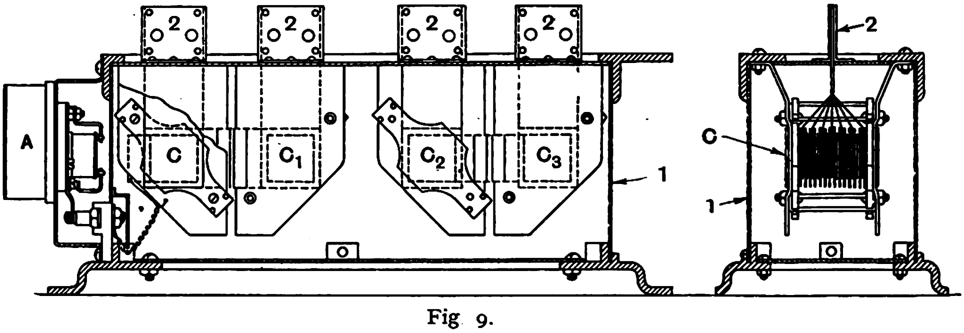


Fig 9.

In the construction of condensers for use in radio-frequency ammeters of this type, it has been found that special precautions are necessary over and above those commonly adopted in the design of mica condensers for use in radio-frequency circuits. In the first place, very rigid clamping of the parts of the condenser is essential, and this clamp must be so arranged that it does not form a closed metallic loop surounding the main current path through the instrument. One way in which this desired result may be obtained is indicated in Fig. 7*. In this diagram the sheets of mica dielectric are arranged in square form as shown at *M*, and the metal foil conductors forming the two armatures of the condenser are brought out at adjacent sides of the dielectric pieces as at F_1, F_2, these foils all being soldered together into two groups for the large capacity condenser in the ammeter. The whole condenser is held rigidly together by clamping members C_1, C_2 secured by the bolts *B B*. The current flowing through a condenser constructed in this manner through the conductors F_1 F_2 forms a small loop with which the metallic loop of the clamp itself is not linked, so that energy losses in the clamp are reduced to a minimum, while adequate spacing of the condenser from the clamping members helps also in this direction.

It is very easy to arrange instruments of this type to be suitable for more than one range of current measurements by enclosing more than one main condenser element for the shunt inside the single instrument casing. An instrument having two ranges is illustrated in Fig. 5, the arrangement of the circuit inside the instrument being as sketched in Fig. 8. In this diagram the main insulated terminal is marked T_1, this leading to the first main large capacity condenser element of the shunt C_1, and across this being connected the small capacity condenser C_2 in series with the indicating thermo-ammeter A as before, the second main terminal T_0 being joined to the case of the instrument as indicated. A second main large capacity condenser element C' is also included in the casing, one terminal of the condenser being joined to the case at T_0, the other terminal being brought out as a second insulated terminal T'. These two main condenser elements C_1 and C' are constructed in exactly similar manner and arranged symmetrically inside the casing so that the self-inductances of the two parallel paths through the meter are sensibly the same. The range of the instrument is increased by connecting the two condensers C_1 and C' in parallel. An extension of this idea to the construction of an instrument with four ranges is described and illustrated in the British Patent 277,933.[*], from which the diagram in Fig. 9 has been reproduced. In this diagram four similar condenser elements are shown marked C, C_1, C_2, C_3, respectively, the insulated terminals of these four condensers being brought out to the four insulated terminals marked 2 in the diagram, the whole being enclosed in the metal casing 1 upon one end of which the ammeter A is mounted.

---

* Dubilier Condenser Company, Ltd., *British Patent*, No. 267,568.

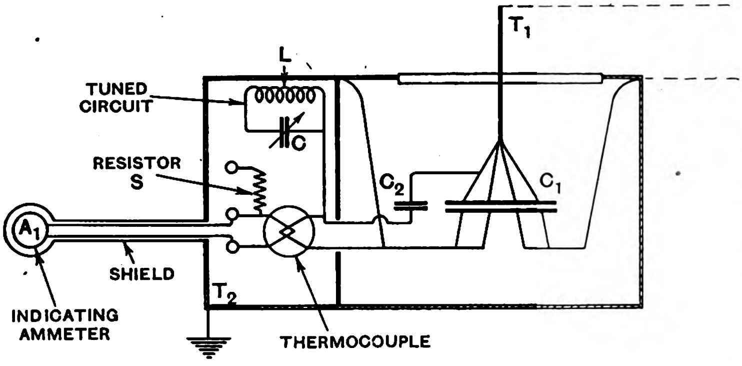


Fig. 10.

An advantage of the use of the thermo-junction ammeters as indicated for instruments of this type is that the indicator portion of the meter can be separated from the main radio-frequency circuit if desired. By arranging the thermo-junction of the indicating ammeter as at A, Fig. 8 with one pole connected to the case of the instrument, which is preferably earthed, the flow of any stray radio-frequency currents through the leads to the indicating meter can be largely avoided, and since the indicator for such thermo-junction meters is a D.C. instrument, the currents flowing through these connecting leads are very small. In Fig. 10 the diagrammatic arrangement is given of one of these meters with a separate indicating instrument spaced away from the main circuit and marked A_1 in the diagram, the other parts being lettered to agree with the parts marked in Fig. 3. With this arrangement the thermocouple is preferably mounted inside the main casing of the instrument so as to shield it from stray radio-frequency fields while the connecting wires are enclosed in a metal tube as also illustrated in the photograph Fig. 6. The thermo-junction used with these meters may be of the ordinary open type, but preferably of the vacuum type sealed into an exhausted glass bulb. Fig. 11 shows such a vacuum thermo-junction connected to a small indicating meter suitable for this class of work, this meter being provided with a special scale graduated to read the true current flowing through the main circuit of the meter. Another

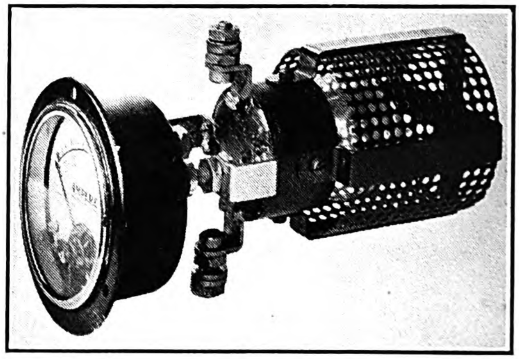


Fig. 11.

---

[*] Issued to the Dubilier Condenser Company, Ltd.

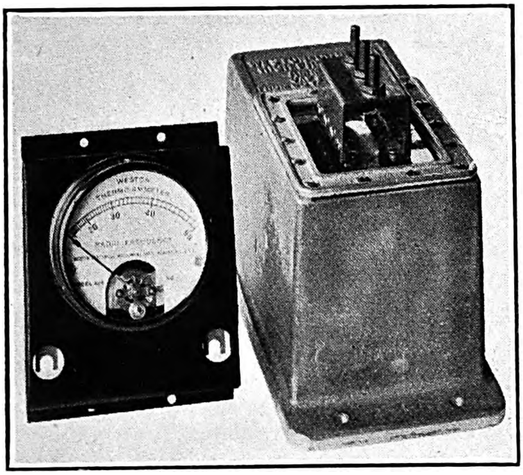


Fig. 12.

arrangement is illustrated in Fig. 12, in which arrangement the indicating meter can be mounted either directly upon the main casing of the meter (as in Fig. 5) or spaced away from it as in Fig. 10, a standard length of connecting leads being used in the latter case. For such an arrangement it is advantageous to include a small resistance marked S in Fig. 10, having an effective resistance equal to that of the leads used to connect up the distant indicating meter. When the indicator is used at a distance it is then connected directly to the thermocouple through the special leads, but when it is used close up to the main meter the connection is shifted over so as to include the resistance S in the meter circuit and retain the same accuracy of calibration.

From tests carried out during the last three years in the Dubilier Laboratories, it has been found that the indications of meters of this type remain consistent and reliable at all times, such that they can be kept as standards for the measurement of radio-frequency currents, their small size and negligible energy dissipation rendering them specially advantageous in this direction, particularly for the measurement of currents at very high frequencies.

The Application of Alignment Charts to Valve Characteristics.*

By M. Reed, M.Sc., A.C.G.I., D.I.C.

In this article it is shown how an alignment chart can be used to obtain the ordinary valve characteristics from the design data of the valve.

For the sake of completeness, an outline of the geometry of the alignment chart used, is given.

Consider an equation of the form:

$$au + bv = c \quad \dots \quad \dots \quad (1)$$

in which a, b, and c are constants and u and v are variables.

Let values of u be marked off along Au and values of v along Bv (Fig. 1). AB is the datum line connecting $u = 0$ with $v = 0$.

Let AD and BF intersect at P. A third line joining two other values of u and v will be found to pass through P also.

Take AB as x axis and OY as y axis,

then $$x = d\left[\frac{b - a}{a + b}\right] \quad \dots \quad \dots \quad (2)$$

and $$y = \frac{c}{a + b} \quad \dots \quad \dots \quad (3)$$

Thus x depends only on a and b, whereas y is directly proportional to c. Therefore, if c is now considered as a third variable, its successive values will give a scale of points similar to P along the line CE. This third scale will be parallel to the other two

---

[*] An article on "The Alignment Principle in Calibration," by W. A. Barclay, appeared in EXPERIMENTAL WIRELESS of December, 1925.

as x is still a constant according to equation (2).

Suppose the equation to be charted is:

$$aU + bV = c \quad \ldots \quad \ldots \quad (4)$$

and that scale values have been chosen for U and V so that

$$u = I_1U \quad \text{i.e., } U = u/I_1$$
$$v = I_2V \quad \text{i.e., } V = v/I_2$$

Substitution in (4) gives:

$$auI_2 + bvI_1 = cI_1I_2 \ldots \quad \ldots \quad (5)$$

$$\therefore \quad x = d\left[\frac{bI_1 - aI_2}{aI_2 + bI_1}\right]$$

$$\therefore \quad \frac{bI_1}{aI_2} = \frac{d+x}{d-x} = \frac{AC}{CB} \text{ (see Fig. 1) } \ldots \quad (6)$$

$$\text{and} \quad y = \frac{I_1I_2C}{aI_2 + bI_1} \text{ [see (3)]}$$

From which by similarity with U and V

$$I_3 = \frac{I_1I_2}{aI_2 + bI_1}$$

where I_3 is the scale for the third variable c.

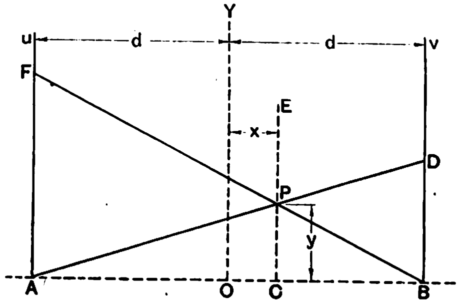


Fig. 1.—From (1) if $u=0$, then $v=c/b$. $\therefore BD=c/b$. Also, if $v=0$, then $u=c/a$. $\therefore AF=c/a$.

Since a scale can be made out for $a\,u$, but actually scaled off in values of u, we can put $a = b = 1$.

$$\therefore \quad I_3 = \frac{I_1I_2}{I_1 + I_2} \text{ and } \frac{AC}{CB} = \frac{I_1}{I_2}$$

This alignment chart will now be used to obtain the ordinary valve characteristics. The relation between the plate current, the plate volts, and the grid volts is given by the expression:

$$I_p = a\left[\frac{E_p}{\mu} + E_g + e\right]^{\beta} \quad \ldots \quad \ldots \quad (7)$$

Where I_p = plate current.
E_p = plate volts
E_g = grid volts
μ = amplification factor of the valve.
a = constant depending on the disposition of the electrodes.
β = constant decided by the shape of the valve characteristics.
e = intrinsic potential between the filament and the system constituted by the grid and plate.

[See Van de Bijl, "Thermionic Vacuum Tube," page 156.]

e is determined by putting $I_p = 0$.

$$\text{i.e., } e = -\left[\frac{E_p}{\mu} + E_g\right] \ldots \quad \ldots \quad (8)$$

where E_p and E_g are the voltages corresponding to $I_p = 0$.

Expression (7) can be used to draw the alignment chart between I_p, E_p, and E_g.

From (7) we have that:

$$\left[\frac{I_p}{a}\right]^{1/\beta} = \left(\frac{E_p}{\mu} + e\right) + E_g$$

comparing this with

$$c = U + V$$

we have that

$$c = \left[\frac{I_p}{a}\right]^{1/\beta} \quad \ldots \quad \ldots \quad (9)$$

$$U = \frac{E_p}{\mu} + e$$

$$V = E_g \text{ for } +ve \text{ bias}$$
$$= -E_g \text{ for } -ve \text{ bias.}$$

It is now necessary to decide the scales.

Let A_p = length of plate volts scale in inches.
A_g = length of grid volts scale in inches.
D = distance between the scales.
$V_a - e$ = maximum value of plate volts.
V_g = maximum value of grid volts.
I_1 = scale for plate volts.
I_2 = scale for grid volts.
I_3 = scale for plate current.

$$\text{Then } I_1 = \frac{V_a}{\mu \, . \, A_p} \text{ and } I_2 = \frac{V_g}{A_g}$$

$$\therefore I_3 = \frac{I_1I_2}{I_1 + I_2} = \frac{V_aV_g}{V_aA_g + \mu V_gA_p} \text{ amps./inch.}$$

∴ from (9) a current of I_p amps will be represented by a length of

$$\left[\frac{I_p}{a}\right]^{\frac{1}{\beta}} \times I_3 \text{ inches} \quad .. \quad (10)$$

Also $$\frac{AC}{CB} = \frac{I_1}{I_2} = \frac{V_a}{\mu V_g} + \frac{A_g}{A_p}$$

$$\therefore \quad \frac{AC}{AC + CB} = A_g V_a / \mu A_p V_g + V_a A_g$$

$$\therefore \quad AC = D \times A_p V_a / \mu A_p V_g + V_a A_g$$

From (8) we have that $I_p = 0$, when $E_g = -\left[\frac{E_p}{\mu} + e\right]$, thus giving the zero on the plate current scale.

The plate current scale can then be calculated according to (10).

The alignment chart can be drawn as in Fig. 2.

It is, therefore, seen that by knowing the values of a, β, and μ, the alignment chart can be drawn. Of these, a and μ depend on the design of the valve, and β is decided by the nature of the electron emission from the filament. From the chart shown in Fig. 2 we can obtain:

(1) The "plate current—grid volts" characteristics.

i.e. For any fixed value of E_p, we can determine the values of I_p corresponding to given values of E_g.

e.g., If we fix E_p at E_p', then from the chart the values of E_g corresponding to $I_p = 0$ and $I_p = I_p'$ are readily determined, and so on.

(2) The "plate volts—grid volts" characteristic for constant values of the plate current.

e.g., If I_p is fixed at 0, then the values of E_g corresponding to $E_p = V_a$ and $E_p = E_p'$ are readily determined, and so on.

(3) The "plate current—plate volts" characteristic.

i.e., For constant values of the grid volts we can easily obtain the corresponding relationship between I_p and E_p.

EXAMPLE.

An example will now be worked out in full for a valve having the following constants.

Filament volts = 4
Filament current = 0.265 amp.
Impedance = 6,000 ohms
$\mu = 6.6$
$a = 0.068 \times 10^{-3}$

For a valve of this type e is generally small and can be neglected.

In practice β varies from about 1.6 to 2.0. In this example $\beta = 1.8$* will be used.

$$\therefore I_p = 0.068 \times 10^{-3}\left[\frac{E_p}{6.6} + E_g\right]^{1.8} \quad .. \quad (11)$$

The range of plate volts will be taken from 30 to 130 volts, and the range of grid volts will be taken from − 20 to + 10 volts.

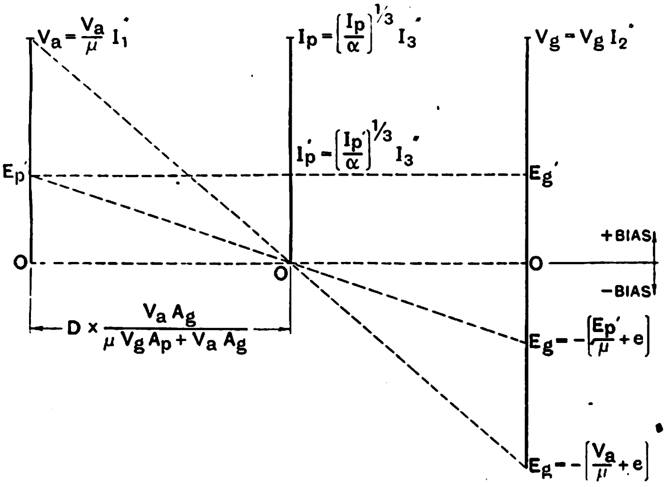

$V_a = \frac{V_a}{\mu} I_1$
$I_p = \left[\frac{I_p}{\alpha}\right]^{1/3} I_3$
$V_g = V_g I_2$
$I_p' = \left[\frac{I_p'}{\alpha}\right]^{1/3} I_3$
E_p'
E_g'
+BIAS
O
O
O
−BIAS
$D \times \frac{V_a A_g}{\mu V_g A_p + V_a A_g}$
$E_g = -\left[\frac{E_p'}{\mu} + e\right]$
$E_g = -\left[\frac{V_a}{\mu} + e\right]$

Fig. 2.

For the plate volts let 1 volt = ¼ in. = I_1, and for the grid volts let 1 volt = ¼ in. = I_2.

$$\therefore \quad I_3 = \frac{I_1 I_2}{I_1 + I_2} = \tfrac{1}{8}''.$$

TABLE I.

PLATE VOLTAGE SCALE.

E_p	$\frac{E_p}{\mu}$	Scale Length in ¼ in.	Scale Length with E_p=30 as Zero.
30 volts	4.55 volts	4.55	0
70 ,,	10.60 ,,	10.60	6.05
100 ,,	15.15 ,,	15.15	10.60
130 ,,	19.70 ,,	19.70	15.15

---

* This value has been found to hold for a number of valves whose characteristics were analysed.

$$\therefore \qquad I_p \text{ amps} = \left[\frac{I_p}{a}\right]^{1/\beta} \times \tfrac{1}{8} \text{ inch.}$$

$$\therefore \quad I_p \text{ milliamps} = \left[\frac{I_p}{0.068}\right]^{1/1\cdot 8} \times \tfrac{1}{8} \text{ inch} \quad .. \ (12)$$

$$\text{also} \qquad \frac{AC}{CB} = \frac{I_1}{I_2} = 1. \qquad \therefore AC = \frac{D}{2}.$$

Tables 1 and 2 give the calculations necessary to graduate the plate volts and the plate current scales. Only a few of the values calculated are given. The grid volts scale is self-evident. The resulting alignment chart is shown in Fig. 3.

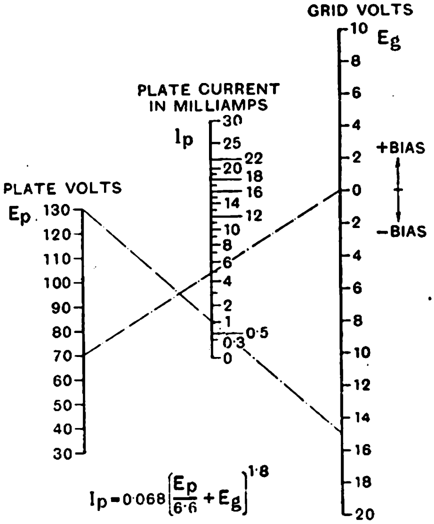


Fig. 3.

To obtain the alignment chart the procedure is as follows:

1. Draw the plate volts and the grid volts scales. These are parallel lines drawn in a convenient position and a suitable distance apart. In the case of Fig. 3, the distance apart is 2 inches.

2. Obtain the zero of the plate current scale. This is obtained by the method given on page 572. In the case of Fig. 3 the zero was obtained by determining the point of intersection of the lines joining $E_p = 130$, $E_g = 19.7$ and $E_p = 100$, $E_g = 15.15$, respectively.

3. Draw a line through the point of intersection parallel to the voltage scales. This line will satisfy the relation $\frac{AC}{CB} = 1$ if the voltage scales have been drawn correctly.

4. Graduate the plate current scale according to the expression given in (12).

In Fig. 3 the method of using the chart is indicated. It is seen that when $E_p = 130$ and $E_g = -15$, the resulting plate current is 1 milliamp. When $E_p = 70$ and $E_g = 0$, the resulting plate current is 5 milliamps. It was found that these values agreed with those given by the ordinary valve characteristic.

One precaution must be taken when using the alignment chart. The expression will not hold when the top bend of the "plate-current—grid-volts" characteristic is reached, therefore the plate current cannot be obtained from the alignment chart for all positive values of the grid volts. The following working rule can be used. If E_g is the value of the grid volts necessary to reduce the plate current to zero for a given plate voltage, then $E_g/3$ is the maximum positive value of the grid volts for which the plate current should be determined from the alignment chart for the given value of the plate voltage.

TABLE II.

Plate Current Scale.

I_p in Milliamps.	$(I_p)^{1/1.8}$	$(I_p)^{1/1.8} \times \frac{0{\cdot}5}{(0.068)^{1/1.8}}$	Scale Length in ¼ in.
0	0	0	0
5	2.44	5.15	5.15
10	3.60	7.90	7.90
15	4.50	9.90	9.90
20	5.30	11.65	11.65
30	6.60	14.50	14.50

Polar Diagrams Due to Plane Aerial Reflector Systems.

By T. Walmsley, B.Sc. (Lond.), Assoc.M.Inst.C.E., M.I.R.E.

IN descriptions of reflector or "beam" systems it is customary to plot the polar diagram in a horizontal plane only (*e.g.*, Marconi "Radio Communication," Proc. I.R.E., 1928, No. 1) with the result that radiation behind the reflector is shown as being either negligible or very small.

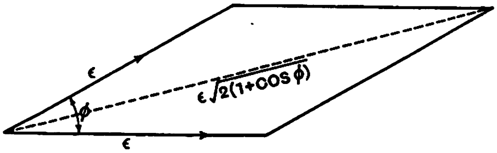


Fig. 1.

The purpose of these notes is to obtain formulæ to enable the polar diagram in any vertical plane to be plotted and thereby to explain the well-known fact that field strength behind the reflector is considerable. For this purpose the complex field due to the exciter array is calculated.

The field due to the reflector is similar to that due to the exciter, assuming similar current distribution in the wires. It differs in phase, however. The difference between the phase angles being known, then, by a simple combination of vectors an expression may be deduced which, used as a multiplier of the field strength due to the exciter, gives the total field strength of the combined aerials. The value of this multiplier, assuming equal amplitudes of currents in reflector and exciter, is $\sqrt{2(1+\cos\phi)}$ where ϕ is the difference in phase. Fig. 1 illustrates this statement.

The problem is to ascertain the effect of a reflector upon an exciting aerial, at all angles in any vertical plane.

Take an exciter made up of a number of grounded wires and consider the electric field strength at a point P distant r_o from the base of the exciter system.

Let P (Fig. 2) be in a plane making an angle α with the vertical plane normal to the array.

Levin and Young* have shown that the field strength E, due to a single grounded vertical antenna is

$$E = -\frac{2a}{c\,r_o}\cos\frac{2\pi}{\lambda}(ct - r_o)\cos\left(\frac{B\cos\psi}{\sin\psi}\right)$$

where $$a = \frac{\pi}{2}n\left(1 + \frac{4d_o)}{\lambda_0}\right)$$

$$n = \frac{\lambda}{\lambda} = 4 \times \frac{\text{length of ungrounded antenna}}{\text{operating wavelength.}}$$

d_o = distance of lower end of antenna from ground (= o in this case).

$$\beta = \frac{\pi}{2}n$$

ψ = angle between horizontal and line jointing P to the base O of the antenna, and c = velocity of light.

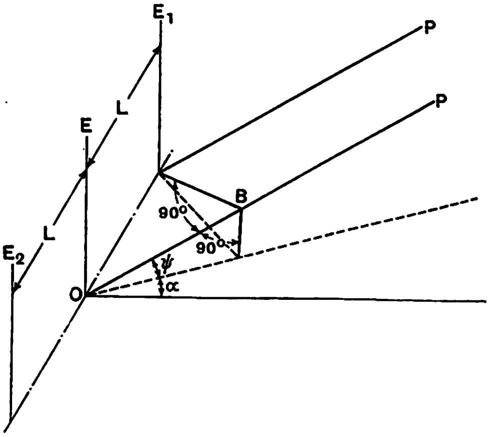


Fig. 2.

Now consider an array such as shown in Fig. 2 having equal currents in each wire. All lines drawn from P to each reflector wire may be regarded as parallel.

Hence the value of the electric field at P due to the current in E_1 will be equal in amplitude and similar in wave form to that due to the current in E. It will, however, lead in phase by an angle proportional to the length OB.

---

* *Proc. I.R.E.*, Vol. 14, No. 5, 1926.

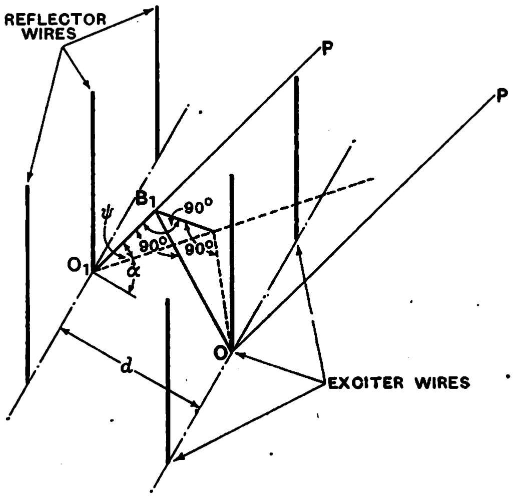


Fig. 3.

If $OB = X$, the angle of lead $= \dfrac{X}{\lambda} \cdot 2\pi$,

but $X = L \cos \psi \sin \alpha$

where L = distance between wires.
ψ = angle between OP and horizontal.
α = angle between the plane and the plane normal to the array.

$$\therefore \quad \text{Angle of lead} = \frac{2\pi L}{\lambda} \cos \psi \sin \alpha$$

Also the angle of lag of wave due to E_2 is equal to the angle of lead of wave due to E_1. Thus if there are N wires on each side of the centre wire

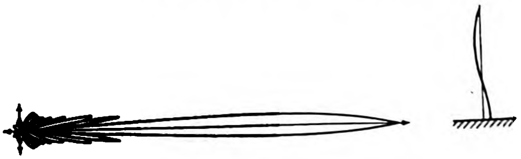
$$\begin{aligned} E = -\frac{2a}{c r_0}\frac{\cos(\beta \sin \psi)}{\cos \psi}\Big[&\cos \frac{2\pi}{\lambda}(ct - r_0) \\ &+ \cos \frac{2\pi}{\lambda}(ct - r_0 + L \cos \psi \sin \alpha) \\ &+ \dots \cos \frac{2\pi}{\lambda}(ct - r_0 + NL \cos \psi \sin \alpha) \\ &+ \cos \frac{2\pi}{\lambda}(ct - r_0 - L \cos \psi \sin \alpha) \\ &+ \dots \cos \frac{2\pi}{\lambda}(ct - r_0 - NL \cos \psi \sin \alpha)\Big] \\ = -\frac{2a}{c r_0}\frac{\cos(\beta \sin \psi)}{\cos \psi}& \end{aligned}$$

$$\times \frac{\left(\cos \frac{2\pi}{\lambda}(ct - r_0) \sin \left\{\frac{2N + 1}{\lambda} . L \cos \psi \sin \alpha\right\}\right.}{\left.\sin \frac{\pi L}{\lambda} . \cos \psi \sin \alpha\right)}$$

To find the phase lag due to an identical system of reflector wires, consider Fig. 3. Then the lag is due to three causes: (i) the time taken by an exciting pulse to travel across distances d; (ii) the lag between the arrival of the exciting pulse at the reflector and the resulting radiated wave; (iii) the time taken by the reflected wave to travel through the distance $O_1B_1 = b$ where OB_1 is perpendicular to O_1B_1.
Now $b = d \cos \psi \cos \alpha$

$$\begin{aligned} \text{Angle of lag} &= \frac{2\pi d}{\lambda} + \pi + \frac{2\pi d}{\lambda} \cos \psi \cos \alpha \\ &= \frac{2\pi d}{\lambda}[1 + \cos \psi \cos \alpha] + \pi \end{aligned}$$

There is considerable controversy as to the justification for regarding the lag due to the distance d as $\frac{2\pi d}{\lambda}$. According to Fleming the magnetic field travelling with infinite speed is the exciting influence upon the reflector. Fleming, however, confines his remarks to reflectors spaced $\lambda/4$ from the exciter. He makes no reference to reflectors spaced more than $\lambda/4$, at which distance true radiation due to the exciting aerial is stated to begin. Sometimes a reflector is placed $3\lambda/4$ behind the exciting aerial and as at this distance the influencing magnetic field will be much less than that due to the exciter electric radiation, there would appear to be some justification for accepting the value $\frac{2\pi d}{\lambda}$ for the lag. Again, the value π for the phase angle between exciting influence and reflected radiation might be too great. However, even if π is too great and a correct



(a) (b)

Fig. 4.

value is, say, δ, the sum $\frac{2\pi d}{\lambda} + \delta$ can be made equal to the value assumed in the calculation by increasing the distance *d*.

The need for a reflector which is readily capable of horizontal adjustment is thus apparent. Although a knowledge of the accurate value of the phase angle difference is essential for exact calculation, inaccuracy does not vitiate the general conclusion of this article.

Results.

In Figs. 4 to 6 the polar diagrams for various values of α are given for a 15-wire aerial with a 15-wire reflector, the spacing between wires being 0.62λ and the reflector $\lambda/4$ behind the exciter. These have been obtained by multiplying the value of E due to the exciter by the reflector expression $\sqrt{2(1 + \cos\phi)}$ where ϕ

$$= \frac{2\pi d}{\lambda}[1 + \cos\psi\cos\alpha] + \pi$$

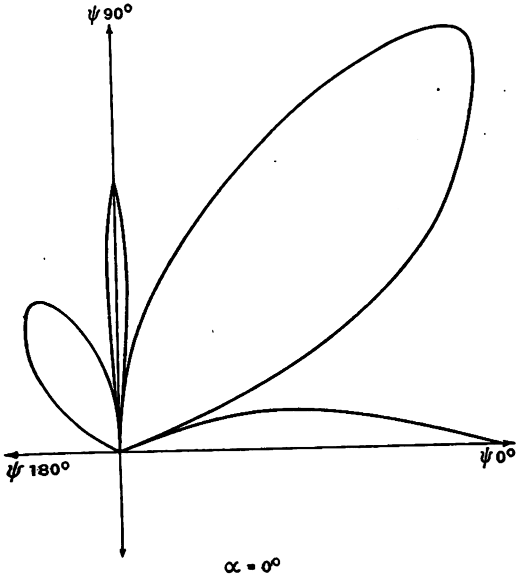


Fig. 5.

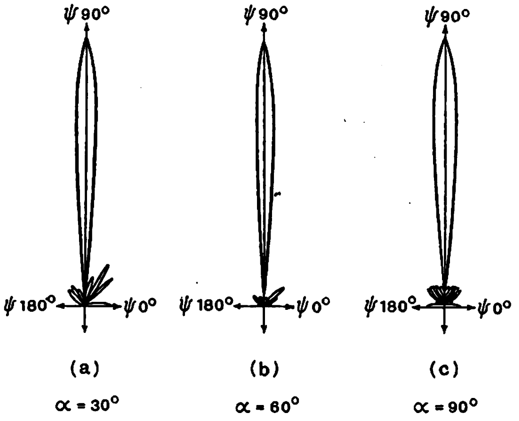


Fig. 6.

Fig. 4a shows the horizontal polar diagram. Fig. 4b shows the assumed current distribution. Horizontal radiation behind the reflector is here seen to be zero or approximately zero. The remaining curves give, for the particular type of aerial excitation considered, the radiation in vertical planes making angles of 0 deg., 30 deg., 60 deg. and 90 deg. to the normal to the array. When this angle is 0, *i.e.*, in the normal plane, the backward radiation about an angle of 120 deg. to the horizontal is quite considerable. The refraction or reflection of this radiation by the upper ionised layer will thus give rise to an appreciable field strength behind the reflector.

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

Les Phénomènes de Propagation des Ondes Radiotélégraphiques (The phenomena of propagation of radio-telegraphic waves).—R. Jouast. (*Comptes Rendus*, 23rd July, 1928, V. 187, pp. 208–209.)

The writer maintains that the usual "ionised layer" theory is inadequate, and that it does not cover the phenomenon of echoes, single or multiple, shown by the "jab" method of short signals; for not only are these echoes apparent a few kilometres from the transmitter (whereas rays reflected from such a layer would only return to earth at much greater distance), but they appear to come from a height of 200–400 km., this height often varying within a few seconds. Maurain and others have shown that the relations between solar activity and terrestrial magnetic conditions suggest that the variations of the magnetic constants are due to an ionisation at great altitude produced by those solar particles whose arrival in our atmosphere is often signalised by aurora. The facts that the "echoes" seem to come from a height corresponding with that of the aurora, and that the characteristic green auroral ray is visible in all latitudes, make the writer believe that the same agents produce electron-clouds, of dimensions comparable with the length of wave, at high levels. These clouds would be capable of diffusing the waves in all directions.

The Diamagnetic Layer of the Earth's Atmosphere and its Relation to the Diurnal Variation of Terrestrial Magnetism.—Ross Gunn. (*Phys. Rev.*, July, 1928, V. 32, pp. 133–141.)

An investigation of the motion of ions and electrons in the region of long free paths shows that the electrical conductivity in the direction of the earth's magnetic field is that predicted by simple theory. A theory of the diurnal magnetic variation is worked out which explains quantitatively the major phenomena in terms of the diamagnetic effect produced by ions spiralling about the earth's magnetic field. The average maximum number of ions of all kinds per $cm.^3$ in the upper atmosphere is computed from observed magnetic data, and found to be about 5×10^{10}, a number not inconsistent with the ionic density inferred from radio phenomena.

The Study of Signal Fading.—E. V. Appleton. (*Journ. I.E.E.*, August, 1928, V. 66, pp. 872–881.)

An account of recent work of the Peterborough Radio Research Station of the Department of Scientific and Industrial Research. The method chiefly employed is the wavelength change method. The paper deals particularly with the investigation on waves within the broadcasting band. Among the conclusions arrived at may be mentioned: (1) Fading is chiefly due to the effects of intensity variations, and to a less extent phase-variations, of rays deviated from the upper atmosphere; (2) there are nights when, during the period before dawn, the ionisation in the Kennelly-Heaviside layer has been sufficiently reduced by recombination to permit of its penetration by waves of this frequency, which are, however, deviated by an upper layer richer in ionisation. At sunrise, solar radiation reforms the Kennelly-Heaviside layer at a height of about 100 km.; (3) the downcoming ray is approximately circularly polarised with a left-handed rotation: possibly by the influence of the earth's magnetic field—a critical test would be to repeat in the Southern Hemisphere. The application of the methods to the Solar Eclipse observations is described. The paper is followed by a discussion (pp. 881–885).

Radio Transmission Formulæ.—G. W. Kenrick. (*Phil. Mag.*, August, 1928, V. 6, pp. 289–304.)

By an application of the optical point of view, and a direct summation of the reflected rays, the author derives an expression for the field between two concentric conducting spheres, and considers its application to the problem of long-distance radio communication. The first part of the work, dealing with propagation between two perfectly conducting planes, is not limited to long-distance, long-wave communication; but certain approximations introduced in correcting for earth curvature and for finite conductivity need further investigation before the method can be applied to short-wave communication over short or moderate distances. On long-wave, long-distance work the author compares his formulæ with the original Austin formulæ.

Recent Research in Greenland on Terrestrial Magnetism.—de la Cour. (*Nature*, 28th July, 1928, V. 122, p. 153.)

A paragraph regarding a paper read before the Royal Danish Academy of Science and Letters, on the work of the Godhavn Observatory, where research on magnetic variations near the Magnetic Pole is being carried on.

Zur Theorie der Lichtzerstreuung in der Erd-Atmosphäre (The Theory of Light Dispersion in the Earth's Atmosphere).—J. J. Tichanowsky. (*Physik. Zeitschr.*, 1st July, 1928, V. 29, pp. 442–447.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

Atmospheric Measurements at the Shuan-Chiao Radio Station.—Kinase, Maeda and Saito. (*Journ. I.E.E., Japan*, April, 1928, pp. 427–445.)

On the Sources of Atmospherics Received in Japan.—J. Obata. (*Journ. I.E.E., Japan*, July, 1928, pp. 712–721.)

Among the conclusions may be mentioned that a permanent source of atmospherics (except in winter) seems to exist at a bearing 300° to 330° from Tokio.

Another seems to be in the S.W. direction, presumably in the tropics: disturbances from here continue in the winter.

Observations sur les Perturbations Atmosphériques dans les Îles Kouriles Septentrionales (Atmospherics in the N. Kurile Islands).—Nagashima and Matsudaira. (*Journ. I.E.E., Japan*, March, 1928, pp. 277–283.)

The directional measurement was carried out on a receiver with cardioid polar diagram and tuned to 7,700 m. Intensity and number per minute were judged by the shunted telephone method. Disturbances were more intense at night than by day, and increased from July to August and September. The majority came from the direction of the mountainous parts of the island and of the Kamschatka peninsula. No definite correlation between atmospherics and meteorological conditions could be defined, but showers and storms were always preceded by a continuous whistling lasting several minutes.

On Thunderstorms in Japan and Recent Theories of Thunder Electricity.—S. Fujiwara. (*Journ. I.E.E., Japan*, June, 1928, pp. 634–646.)

Rendering Visible a Magnetic Field.—Elihu Thomson. (*Scientific American*, September, 1928, pp. 236–239.)

The author describes an optical phenomenon due to the effect of a magnetic field on the iron smoke produced by an electric welder, and suggests that it offers an explanation of the Zodiacal light.

Large Magnetic Storms and Large Sunspots.—Greaves and Newton. (*Monthly Notices Roy. Astron. Soc.*, May, 1928; summarised in *Nature*, 4th August, 1928.)

Discusses the occurrence of sunspots at the time of magnetic storms for the years 1874 to 1927.

Electric Potential Gradient Measurements at Eskdalemuir, 1913–23.—R. A. Watson. (*Geophys. Mem. Met. Office*, No. 38, 1928; summarised *Nature*, 18th August, 1928.)

Contrary to Bauer's conclusion from the first eight years' data, the writer finds no significant indication of a connection between sunspot numbers and the departure of the mean gradient in any month from its eleven-year mean for that month. A theory of the connection between gradient and wind is outlined.

The Reduction of Atmospheric Disturbances.—J. R. Carson. (*Proc. I. Rad. Eng.*, July, 1928. V. 16, pp. 966–975.)

Analyses an arrangement which provides for H.F. selection plus L.F. balancing after detection, and refers particularly to Armstrong's recent proposal (*cf.* March Abstracts). The conclusions are entirely negative; that is, no appreciable gain is to be expected from balancing arrangements.

Sur la Loi de Constitution de l'Atmosphère (The law of atmospheric constitution).—Esnault-Pelterie. (*Comptes Rendus*, 23rd July, 1928, V. 187, pp. 241–242.)

More about the author's formula for determining altitude (*cf.* September Abstracts). He derives from his calculations the result that at a height of 5,170 metres μ is almost exactly independent of T_0, the ground temperature.

Méthode Pratique de Calcul de la Rigidité Diélectrique de l'Air (A practical method of calculating the dielectric strength of air).—G. Devillez. (*Bull. d. L. Soc. Belge des Élec.*, January, 1928, V. 42, pp. 1–28.)

The methods developed are shown to agree quite well with experimental results obtained with various shapes of electrodes.

PROPERTIES OF CIRCUITS.

Stabilisation des Oscillations de Relaxation (Stabilisation of "oscillations of relaxation").—Bedeau and de Mare. (*Comptes Rendus*, 23 July, 1928, V. 187, pp. 209–210.)

Van der Pol has recently shown that the oscillations named by him "oscillations of relaxation" are not very constant in period. The writers have stabilised them by an electrically driven tuning fork, and by using three neon tubes—the first (thus controlled) controlling the second, the second controlling the third—have obtained simultaneously three groups of flashes, at 10^{-1}, 10^{-2} and 1 per second. The last can be compared with a chronometer. The apparatus can be adapted for determining radio frequencies (cf. Decaux, July Abstracts).

La Question d'Amplification. II. La Rétroaction.—P. Olinet. (*Q.S.T. Fran.*, Aug., 1928, pp. 52–57.)

The first paper in this series defined amplification as the functioning of a relay, and gave various examples. The present part deals with thermionic valves from this point of view, and shows that the increase of amplification due to reaction arises from modification not of the relay itself but of the output and (particularly) the input circuits. The latter part of this paper deals with the mathematical derivation of the amplification constant under various conditions of coupling.

Distortion Correction in Electrical Circuits with Constant Resistance Recurrent Networks.—O. J. Zobel. (*Bell Tech. Journ.*, July, 1928, V.7, pp. 438–534.)

Takes up first the general problem of distortion correction, then this method of correction and its application—*e.g.*, for phase correction in the transatlantic telephone system.

Über die Spannungsverstärkung Mittels Transformatorenkopplung beim Niederfrequenzverstärker (Voltage Amplification by Transformer-coupling in L.F. Amplifiers).—H. Reppisch. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, pp. 22–24.)

The physical constants of L.F. intervalve transformers are investigated. It is shown that where, for speech and music amplification, a uniform amplification is desired over a large frequency range, this can be obtained by using a small turns-ratio and keeping the losses small. With turns-ratio $u = 4$, a satisfactorily uniform curve over about 8 octaves can be obtained. The author quotes recent workers who have maintained that with resonance, the voltage-ratio cannot reach the magnitude of the turns-ratio, whereas he shows that under certain conditions it can actually exceed it.

Sur un Dispositif Électromagnétique de Lampes à Trois Électrodes (An electromagnetic arrangement of three-electrode valves).—J. F. Thovert. (*Rev. Gén. d. l'Élec.*, 28 July, 1928, V. 24, p. 152.)

The plate of the first valve is connected through a small battery to the grid of the second valve. The voltage of this battery (which may be a small dry cell) is chosen according to the valve used (between 0 and 10 v.). With a power valve in the second stage, an overall amplification of the order of 10^7 to 10^8 is obtained. The time constant is of the order of one minute.

Equilibres Instables et Régimes Statiques Parasites dans les Circuits Électriques Associés aux Triodes (Conditions of unstable equilibrium and of parasitic disturbances in electric circuits associated with 3-electrode valves.)—Podliasky. (*L'Onde Élec.*, July, 1928, pp. 287–306.)

The present instalment deals with the internal and external characteristics of the Dynatron, but by the word dynatron is included ordinary types of valve used as a dynatron—*i.e.*, used in such a circuit that the secondary emission is preponderant.

Zur Frage Über die Energieverteilung Zwischen dem Sender und dem Regenerativen Empfänger (The distribution of energy between transmitter and regenerative receiver).—G. Ostroumoff. (*Ann. d. Phys.*, 24th May, 1928, V. 85, pp. 1103–1112.)

TRANSMISSION.

On the Wireless Beam of Short Electric Waves: High Angle Radiation of Horizontally Polarised Waves.—S. Uda. (*Journ. I.E.E., Japan*, April, 1928, pp. 395–405.)

Wavelength was 260 cms. Transmitting aerial (length nearly a half wavelength) was placed horizontally above the ground; receiving aerial, also horizontal, was moved up and down in a vertical line, measuring the field intensity at various angles to the ground. Polar diagrams show that the radiation is chiefly at high angles, being very small along the earth's surface.

If height of transmitting aerial $h = \frac{\lambda}{8}$ or $\frac{\lambda}{4}$, maximum radiation will be vertically upwards; if $h = \frac{3}{8}\lambda$ or $\frac{\lambda}{2}$, it will make 45° or 30° with the horizontal. If h is increased to $\frac{5}{8}\lambda$ or $\frac{3}{4}\lambda$, two maxima appear—one upwards, the other at 25° or 20° respectively; if $h = \frac{7}{8}\lambda$ or λ, the two maxima become 60° and 15°, or 50° and 13° respectively. A series of wave directors produces added sharpness of beam, maximum radiation lying not exactly along the line of directors, but at a rather higher angle. (cf. Yagi, September Abstracts: Uda, February Abstracts).

La Direction des Ondes Radioélectriques. Radio-communications par Ondes Courtes Projetées (The direction of radioelectric waves. Radio communication by directed short waves).—L. Bouthillon. (*Bull. d.l. Soc. Franc. d. Physique*, 18 May, 1928, pp. 84S–85S.)

A general survey, including an outline of the general theory and of the various methods of carrying it out.

Die Erzeugung Sehr Kurzer Elektrischer Wellen mit Wechselspannung nach der Methode von Barkhausen und Kurz (The production of ultra-short waves by the B-K method but with A.C. voltage).—W. Wechsung. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, pp. 15–18.)

The first part of a long paper in which the author sets out to investigate, by methods using both D.C. and A.C. voltages, the results of Barkhausen and Kurz, Gill and Morell, and Saháněk, which were all based on D.C. voltage.

Über die Günstigste Belastung des Hochfrequenz-generators (The Optimum Loading of the H.F. Generator).—Y. Watanabe. (*E.N.T.*, July 1928, V. 5, pp. 259–267.)

Since the internal inductive reactance is considerable, it is often necessary to compensate by a capacitive reactance. The correct value is worked out for the two cases: (*a*) where the load is given in volt-ampères, and (b) for a given power-loss in the generator.

Telephonie auf Extrem Kurzen Wellen (Telephony on ultra-short waves).—H. E. Hollmann. (*E.N.T.*, July, 1928, V. 5, pp. 268–275.)

The transmitters described used wavelengths from 38 to 100 cms., and in a closed oscillating circuit give from 0.16 to 0.51 ampere. For telegraphy, tonic train is employed; for telephony, modulation is obtained by parallel control-valve or by D.C. modulation (grid or anode) with or without an amplifier-valve. Parallel wires with movable bridge are used as oscillating circuits both for transmitter and receiver, together with a dipole antenna, each pole of which is extensible for tuning. Using a single-valve receiver, distances of 500 wavelengths have so far been covered without using a " beam."

Recent Development in Low Power and Broadcast Transmitters.—(*Proc. I. Rad. Eng.*, July, 1928, V. 16, pp. 981–982.)

Discussion on Byrnes' paper (cf. August Abstracts) which, however, is limited to the part dealing with quantitative data on harmonic radiation.

RECEPTION.

Sur la Qualité de la Reproduction Radiophonique (The quality of radiophonic reproduction).—P. David. (*L'Onde Élec.*, July, 1928, pp. 309–312.)

The author's conclusion is that the average receiver is far too selective and loses too much of the higher frequencies. He recommends increasing the damping and suppressing reaction, or the use of true band filters, etc., sacrificing for good quality the number of stations received.

Spannungsbegrenzer für Verstärker (Voltage Limitation for Amplifiers).—O. Kappelmayer. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, pp. 25–26.)

Former methods of automatic volume-control have worked on H.F. amplification (cf. Wheeler, these Abstracts, March, 1928). The author describes a simple method for L.F. amplifiers, using one of the " relay glow-lamps " (Richter and Heffcken) to limit the amplitude of the A.C. voltage on the grid of the final valve.

Moving Coil Modifications.—L. E. T. Branch. (*Wireless World*, 1 Aug., 1928, V. 23, pp. 122–124.)

The author recommends virtually short-circuiting the inductance of the moving coil by wrapping round the inside or outside with a thin strip of copper. Various advantages are described.

The Output Stage and the Moving Coil: How Relative Impedances affect Quality.—N. W. McLachlan. (*Wireless World*, 8 Aug., 1928, V. 23, pp. 154–157.)

Mains Supply for Valve Receivers.—(*See several articles*, *Wireless World*, 22 August, 1928, V. 23.)

Compromise in Receiver Design (Part 5. The H.F. Amplifier. How the Tuned Circuits Affect Quality).—(*Wireless World*, 29 August, 1928, V. 23, pp. 242–245.)

This instalment of a series begun in the issue for 25th July, contains the following sections: the comparative advantages of the screened valve and the neutrodyne: the subject of screening (not merely for the sake of stability): sensitivity and selectivity versus quality: detuning and quality: good quality with high selectivity is possible.

The Reduction of Atmospheric Disturbances.—J. R. Carson. (*See under " Atmospherics."*)

Fernempfang mit Mehrfachröhren (Distant reception with multiple-valves).—R. Neuroth (*Rad. f. Alle*, July, 1928, pp. 298–304.)

Multiple valves are generally used for local reception. The writer shows how to extend their use to distant reception; taking as an example, the Loewe triple (L.F.) valve, he shows how this can be extended by 1, 2 or 3 stages of H.F. amplification; or by one Loewe double (H.F.) valve.

VALVES AND THERMIONICS.

Thermal Agitation of Electricity in Conductors.—J. B. Johnson. (*Phys. Rev.*, July, 1928, V. 32, pp. 97–109.); and Thermal Agitation of Electric Charge in Conductors.—H. Nyquist (*ibid.*, pp. 110–113).

The author of the first paper reports the discovery and measurement of an E.M.F. in conductors which is related in a simple manner to the temperature of the conductor and which is attributed to the thermal agitation of the carriers of electricity in the conductors. The effect is one (in fact, often the greatest) of the causes of valve noise in amplifiers: The possibility of such an effect was recognised on theoretical grounds by Schottky, who, however, concluded that it would be so small as to be masked by the small-shot (" schrot ") effect. Under certain conditions this is by no means the case, *e.g.*, when a good amplifier has a high resistance between grid and filament of the first valve on the input side. The effect has also made itself felt in experiments with highly sensitive string galvanometers by Dutch workers. It seems that galvanometric measurements of D.C. of less than 10^{-12} amp. become unreliable, just as the alternating potential of 10^{-6} volt marks the critical region for amplifiers.

The second paper is a calculation of the electromotive force due to thermal agitation in conductors, by means of principles in thermodynamics and statistical mechanics. The results agree with the experimental findings.

Les Différentes Méthodes de Détermination de la Condition d'Entretien des Oscillations dans les Émetteurs à Lampes (The different methods of determining the conditions for the maintenance of oscillations in valve transmitters).—F. Bedeau. (*L'Onde Élec.*, July, 1928, pp. 265–286.)

A comparison of the four " classic " methods: Gutton's, where the negative end of the filament is taken as the origin of potentials; Hull's, where the valve is regarded as a relay; the method where the valve is regarded as a circuit of negative resistance (adopted by Blondel and Gutton); and the method based on " curves of work and coupling " (Groszkowski). Among other applications, the case of a tuned amplifier using screened grid valves is dealt with.

SCHROT-EFFECT IN HIGH FREQUENCY CIRCUITS.—S. Ballantine. (*Journ. Franklin Inst.*, August, 1928, V. 206, pp. 159–167.)

The writer points out that all the theoretical work done hitherto on the schrot-effect in thermionic circuits has considered only the gross phenomena, and the assumption underlying all this work has been that the period of the LC-circuit connected to the schrot-tube is long compared with the time of passage of the electron. He therefore investigates the effect in H.F. circuits, when this condition no longer obtains and a microscopic view of the electron's flight must be taken.

UNE SUGGESTION NOUVELLE POUR AUGMENTER L'EFFICACITÉ DE LA DÉTECTION (A New Suggestion for increasing the Efficiency of Detection).—J. Marcot. (*Q.S.T. Fran.*, August, 1928, p. 42.)

For the detection of weak signals by grid-circuit rectification, the efficiency is greater the slower the electrons. Postumus separates out the slower electrons by means of a magnetic field, leading them to a special grid and thus improving detection.

EINE GROSS-VERSTARKERRÖHRE MIT QUECKSILBERDAMPF (A high-power Mercury Vapour Valve).—E. Lübcke. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, pp. 1–10.)

This valve works at 220 v., with an anode current up to 5 amps. (in special cases up to 14 amps.), which is controlled by a grid. Internal resistance is about 70 ohms. It is thus suitable for power work as well as for many other purposes. Applications described include: the regulation of generators and motors; as power valve for powerful loud speakers; as generator for note-frequencies (500–20,000 cycles) and as amplifier down to wavelengths of 100 metres. The work has been done at the Siemens Laboratory.

THE EFFECTS PRODUCED BY POSITIVE ION BOMBARDMENT OF SOLIDS: METALLIC IONS.—M. L. Oliphant. (*Proc. Camb. Phil. Soc.*, July, 1928, V. 24, pp. 451–479.)

The primary object of these experiments was to deduce something of the nature of the energy exchange in a collision between ion and atom in the surface of the bombarded substance, by measurements of the minimum potential required to produce sputtering. They were unsuccessful in this respect, but revealed several points of interest: *e.g.*, the magnitude of the effects which have to be attributed to layers of absorbed gas over the target, and the support given to the photo-electric theory of the production of electrons by neutralisation of positive ions at the cathode.

IONEN UND ELEKTRONEN IN DER VAKUUMGLÜHLAMPE (Ions and electrons in incandescent lamps).—P. Selényi. (*Physik. Zeitschr.*, 15th May, 1928, V. 29, pp. 311–318.)

Among other things, the writer shows how the lamp can be used as detector, magnetron, photocell and vacuum-meter; and describes methods by which the vacuum of a completed lamp may be determined.

ÜBER DIE VERGRÖSSERUNG DES SATTIGUNGSSTROMES VON GLÜHKATHODEN DURCH STARKE ELEKTRISCHE FELDER (The Increase of Saturation Current through Strong Electric Fields).—W. S. Pforte. (*Zeitschr. f. Phys.*, 8th June, 1928, V. 49, pp. 46–51.)

Tests are quoted from which it would appear that Schottky's theory holds good from 1,400 to 2,100° abs., and for fields up to $0.7.10^6$V/cm.

ÜBER DEN MECHANISMUS VON ELEKTRONEN SCHWINGUNGEN (The Mechanism of Electron-oscillations).—H. E. Hollmann. (*Ann. d. Phys.*, 5th June, 1928, V. 86, pp. 129–187.)

Four different frequency zones have been found, with the circuit arrangements used by Barkhausen and Kurz, Gill and Morrell. The shortest wave so far obtained was 21.4 cm., but one of 15 cm. is indicated as being obtainable.

DIRECTIONAL WIRELESS.

DEVELOPMENT OF RADIO AIDS TO AIR NAVIGATION.—Dellinger and Pratt. (*Proc. I. Rad. Eng.*, July, 1928, V. 16, pp. 890–920.)

Deals chiefly with more or less unsuccessful attempts to adapt the "equi-signal zone" crossed-coil beacon (referred to in the August and September Abstracts) to give satisfactory visual indication, leading up to an apparently highly successful conclusion. The goniometer now has two sets of rotor coils in series, each set being in the field of one of the stator coils. This reduces the coupling between the latter; it is further reduced by screening and by earthing the rotor systems at their mid-points. Two independent modulation frequencies (65 and 85) are supplied, taking the place of the interlocked "A" and "N" signals; two vibrating polarised steel or composite reeds are used as indicators, their tips being white in a dark background so that when vibrating each appears as a white line: if the pilot is on the right course, the two white lines are equal. Successful flights have been made up to 135 miles, in fog and over hazardous mountain terrain. The beacons will be placed not over 200 miles apart. Small "marker" beacons at intervals along the route will send out characteristic signals showing on the visual indicator what point is being flown over.

RADIO DIRECTION-FINDER: PART I—THE THEORY OF THE FRAME AERIAL: AVOIDING ELECTROSTATIC PICK-UP.—R. L. Smith-Rose. (*Wireless World*, 15th August, 1928, V. 23, pp. 186–188.)

The second and final instalment, giving design data for a practical direction finder, appears in the issue dated 29th August.

MEASUREMENTS AND STANDARDS.

STUDY ON THE NATURAL ELECTRICAL OSCILLATIONS OF CONICAL COILS.—I. Yamamoto. (*Journ. I.E.E., Japan*, April, 1928, pp. 375–383.)

EINE EINFACHE METHODE ZUR MESSUNG DER EIGENWELLENLÄNGE VON ANTENNEN (A Simple Method of Measuring the Natural Wavelength of an Aerial).—H. Bruun. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, p. 25.)

Methods depending on plotting curves, with varying inductance and capacity in series with the aerial, demand at least six or eight observations. The present method is designed to obtain an equal accuracy with one single observation. A small valve transmitter calibrated in wavelengths is very loosely coupled to a loop connected in series with the aerial. Resonance results in a minimum grid current, as shown on an indicator included in the instrument. It is not clear how allowance is made for the effect of the added loop.

THE NATURAL PERIOD OF LINEAR CONDUCTORS.—C. R. Englund. (*Bell Tech. Journ.*, July, 1928, V. 7, pp. 404–419.)

Describes the experimental determination of the frequency of free electrical oscillation of straight rods and circular loops. The results agree more closely with Abraham's formula ($\lambda/l = 2$, with a correcting term) than with Macdonald's ($\lambda/l = 2.53$). The writer found that a quarter wavelength Lecher frame was a very satisfactory wavemeter for the short waves, giving easily an accuracy of 1 part in 2,500.

DIE PHYSIKALISCHEN GRUNDLAGEN UND DIE TECHNIK DER FELDSTARKEMESSUNG IN DER DRAHTLOSEN TELEGRAPHIE (The theory and practice of Field Strength Measurement in Wireless).—M. Bäumler. (*T.F.T.*, July, 1928, V. 17, 193–199.)

Based on the methods of the German G.P.O.

CHARACTERISTICS OF CERTAIN BROADCASTING ANTENNAS AT THE S. SCHENECTADY DEVELOPMENT STATION.—H. M. O'Neill. (*Proc. I. Rad. Eng.*, July, 1928, V. 16, pp. 872–889.)

The radiation efficiencies of various types of broadcast aerials are compared by field intensity measurements on a constant radius several wavelengths long. The comparisons are subject to the limitation that in thus comparing different aerials it is not certain to what extent an increased average intensity is due to greater concentration of power close to the horizon rather than to increased radiation efficiency. The measure of radiated power is expressed in arbitrary units, the author considering the present radiation formula and field intensity standard to be insufficiently correct to justify expressing the result in Watts.

The effect on signal strength, as measured locally, of varying aerial height is considered; also the effect of high steel towers on aerials operated at 380 m. wavelengths. Aerial ground system losses, local radiation losses, directional effects and field distortion are discussed to a limited extent.

SOME PRACTICAL APPLICATIONS OF QUARTZ RESONATORS.—Cobbold and Underdown. (*Journ. I.E.E.*, August, 1928, V. 66, pp. 855–871.)

GERÄUSCHMESSUNGEN IN FLUGZEUGEN (Noise Measurements in Aircraft).—Fassbender & Krüger. (*Luftf. forsch.*, 7th May, 1928, V. 1, pp. 117–120).

The noises in various types of aeroplanes were measured by the use of the Siemens-Barkhausen noise-meter. Tables are shown giving the results for varying motor-revolutions and various observation-points.

A SIMPLE METHOD OF MEASUREMENT OF CAPACITY AND HIGH RESISTANCE BY MEANS OF A THERMIONIC VALVE.—G. R. Toshniwal. (*Journ. Sci. Inst.*, July, 1928, V. 5, pp. 219–221.)

Charging a capacity by means of a suitable battery and discharging it through the grid-filament circuit, provided with a suitable leak, allows very small capacity values (*e.g.*, down to 5 cm.) to be determined within 1 per cent. By a similar process, values of high resistance have been obtained.

THE MEASUREMENT OF CAPACITANCE IN TERMS OF RESISTANCE AND FREQUENCY.—Ferguson and Bartlett. (*Bell Tech. Journ.*, July, 1928, V. 7, pp. 420–437.)

The adaptation of a bridge circuit allows such measurement to be made with an accuracy comparable with that of the primary standards. No general limitation is placed on the type of condenser or on the frequency at which the measurement may be made. The method is also applicable to the determination of inductance.

THE MEASUREMENT OF HIGH D.C. POTENTIAL DIFFERENCES WITH APPLICATIONS TO THE CALIBRATION OF ELECTROSCOPES AND ELECTROSTATIC VOLTMETERS.—W. Bender. (*Journ. Opt. Soc. Am.*, July, 1928, V. 17, pp. 72–76.)

An arrangement of series condensers, switches, and a ballistic galvanometer is discussed, by means of which measurements can be made with considerably greater precision than that given by ordinary high voltage electrostatic voltmeters.

THERMOSTAT DESIGN FOR FREQUENCY STANDARDS.—W. A. Morrison. (*Proc. I. Rad. Eng.*, July, 1928, V. 16, pp. 976–980.)

Discusses the advantages of the use of a "temperature attenuating" layer, interposed between the object to be controlled and the region about the responding element; and the best design of such a layer.

SUR LES FORCES ÉLECTROMAGNETIQUES S'EXERÇANT ENTRE CONDUCTEURS (The Electromagnetic Forces Between Conductors).—W. F. Dunton. (*Rev. Gén. de l'Élec.*, 12th May, 1928, V. 23, pp. 819–824.)

The author points out the errors arising when formulæ based on infinitely long conductors are applied in the calculation of apparatus. He derives the correct formulæ for calculating the force between two conductors, parallel or inclined to each other.

traversed by currents of known intensity; and also deals with the case of a moving conductor sliding perpendicularly to two parallel conductors. (*Cf.* "A New Ammeter," August Abstracts.)

The Measurement of the Departure of a Wave Form from the Sine-wave Form.—Benischke and Hammerer. (*E.T.Z.*, 26th July, 1928, V. 49, pp. 1136–1137.)

Conclusion of the argument referred to in September Abstracts.

The Application of a Valve Amplifier to the Measurement of X-Ray and Photoelectric Effects.—C. E. Wynne-Williams. (*Phil. Mag.*, August, 1928, V. 6, pp. 324–334.)

A Thermionic Voltmeter for Measuring the Peak Voltage and the Mean Value of an Alternating Voltage of any Waveform.—G. B. Moullin. (*Journ. I.E.E.*, August, 1928, V. 66, pp. 886–895.)

The application of the arrangement here described is illustrated by curves showing the distortion produced by a 4-stage amplifier.

The Application of the Phonodeik in Determining the Performance of Electro-acoustic Devices.—Miller and Martin. (*Phys. Review*, No. 4, 1928, V. 31, p. 708.)

By this instrument, a sound wave can be photographed as it is received by the ear. Thus the tone as reproduced by some electro-acoustic device can be compared with the original.

Über Neuere Akustische und Insbesondere Elektroakustische Arbeiten (Latest Work on Acoustics and in particular Electro-acoustics).—F. Trendelenburg. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, pp. 27–35.)

This first part of a long survey is limited to Acoustic Methods of Measurement, Sound Analysis, Determination of Frequency Curves of Acoustic Filters, acoustic impedance measurements, etc. Future instalments will deal with sound-field processes; the acoustics of rooms; sound-senders and sound-receivers.

Sur la Distorsion Téléphonique et sa Mesure (Telephonic distortion and its measurement).—P. David. (*Rev. Gén. d. l'Élec.*, 21st July, 1928, V. 24, p. 22D.)

A method depending on the transmission of lists of meaningless monosyllables and the use of the percentage of errors as a measure of the distortion.

A Shielded Bridge for the Measurement of Inductance in Terms of Resistance and Capacity.—B. W. Bartlett. (*Journ. Opt. Soc. Am.*, June, 1928, V. 16, pp. 409–418.)

This modification of the Owen Bridge will measure inductance at frequencies up to 50,000 cycles with an accuracy limited only by the accuracy with which standards of resistance and capacity can be obtained. In the case described, this was ±0.003 per cent. at speech and ±0.05 per cent. at carrier frequencies.

Über Ponderomotorische Wirkungen des Lichtes auf Ungeladene Submikroskopische Körper im Elektrischen Felde (Ponderomotive effect of Light on uncharged submicroscopic bodies in electrical fields).—G. Placzek. (*Zeitschr. f. Phys.*, 4th July, 1928, V. 49, pp. 601–603); and Zum Problem des Radiometers (The Radiometer Problem).—I. Bleibaum. (*Ibid.*, pp. 590–600.)

Measurements of Radiant Energy by Means of the Maxwell-Bartoli Forces.—del Nunzio. (*Ann. R. S. Ing.*, Padua, March, 1927.)

A paper describing the use of the pressure of radiation as a means of measuring the energy contained in a bundle of rays.

A Graphical Method for Calculations by Austin's Formula.—N. P. Suvorov. (*Telegraphia i. Telefonia b.p.*, *Nichny-Novgorod*, June, 1928, V. 9, pp. 251–258.)

Calculation of Radiation Resistance for Directive Short-wave Antennæ.—A. Pistolkors. (*Teleg. i. Telef. b.p.*, *Nichny-Novgorod*, June, 1928, V. 9, pp. 333–347.)

SUBSIDIARY APPARATUS AND MATERIALS

An Amplifier to Adapt the Oscillograph to Low-current Investigations.—S. K. Waldorf. (*Journ. Am. I.E.E.*, Aug., 1928, V. 47, pp. 594–597.)

The use of the D'Arsonval oscillograph can be extended by the specially selected amplifier to currents down to about 5 effective microampères at 1 effective volt.

Note sur Quelques Perfectionnements des Amplificateurs à Courant Continu (Some improvements in amplifiers for continuous current).—Jouaust and Décaux. (*L'Onde Élec.*, July, 1928, pp. 306–308.)

For the amplification of very small differences of D.C. potential, the writers have avoided the complication of many stages by a specially designed two-stage arrangement. The first valve is chosen to have great amplification and high internal resistance, the second so as to give the maximum current variation for a given grid voltage change. The circuit is very stable, and an input variation of 0.005 V produces a change in output current of 2.5 mA.

Nouveau Dispositif Stabilisateur de Tension, Système Soulier (New arrangement for stabilisation of voltage, system Soulier).—(*Rev. Gén. de l'Élec.*, 4th Aug., 1928, V. 24, p. 196.)

A more complete exposition of the arrangement referred to in the August Abstracts. The solenoid with its self-adjusting iron core is connected in series with the condenser and the combination placed across the mains, the working voltage being taken from the condenser terminals. The vectors U_s and U_c, representing the voltages across solenoid and condenser respectively, are each at right angles (in the ideal case) to the vector of the current circulating in the system, and are therefore opposed; if U_r represents the vector of the mains voltage,

$$U_r = U_s - U_c,$$

so that any variation in U_r can be compensated for by a suitable variation in U_s, keeping U_c constant. The condenser used is 200 μF, and the iron core weighs about 2 kg.

Ein Wechselstromkompensator mit Grossen Frequenzumfang (An A.C. compensator with wide frequency-range).—K. Lion. (*E.N.T.*, July, 1928, V. 5, pp. 276–283.)

A simple apparatus consisting of two field coils at right angles, with two rotor coils mounted side by side on the common axis of the whole system. Each rotor can be adjusted separately. The application to amplifier measurements, the quantitative determination of harmonics in amplifiers, microphones, etc., the measurement of mutual inductance, permeability, etc., is described.

Un Nouvel Isolant—la Thiolite (A new insulating material, Thiolite).—(*Bull. d.l. Soc. Fran. des Élec.*, June, 1928, V. 8, pp. 647–648.)

A white powder, capable of being moulded, obtained by the introduction of sulphur into bakelite. Being soluble in alcohol, etc., it can be used as varnish. Resistivity is of the order of 300 million megohms/centimetre, dielectric strength is high and H.F. losses small. S.I.C. is 4.5.

Primary Wet Cells.—A. M. Codd. (*Elec. Rev.*, 10th August, 1928, V. 103, pp. 223–226.)

Includes a description of the "Codd" primary cell using a zinc mushroom-form element, one or more carbon plates or rods, and an electrolyte of ferric chloride. 1.2V is the working voltage.

Ein Elektrometer Für Messung Sehr Hoher Gleich- und Wechselspannungen (An Electrometer for very high direct and alternating potentials).—Starke and Schroeder. (*Arch. f. Elektrot.*, June, 1928, V. 20, pp. 115–122.)

This instrument will measure up to 300 kilovolts with accuracy, and can be designed for still greater voltages.

See also H. Dember, *Phys. Zeitschr.*, 1st June, 1928), "A Simple Arrangement for Measuring High Electric Potentials.")

Renseignements sur une Nouvelle Matière Isolante pour la Haute Tension (Information on a new high tension insulating material).—W. Meyer. (*Rév. Gén. de l'Élec.*, 30th June, 1928, V. 23, p. 244D.)

Extract from *Bull. A.S.E.*, 22nd March, 1928, concerning "Di-El" manufactured at Oerlikon: a distillation product which is non-hygroscopic and unaffected by the atmosphere: resistance to compression 800 kg./cm², to extension 500 kg., to bending 550–1,400 kg. It stands up to very high pressures in air or in oil: no actual values are here given.

Étude des Valves de Redressement (Rectifiers of valve form).—Y. Doucet. (*Q.S.T. Franç.*, July, 1928, pp. 5–11.)

I. Electronic valves: the original Fleming valve and its descendants, including the Kenotron. Limited to small currents, the largest output mentioned (so far as valves on the "amateur" market are concerned) being 125 mA. at 200 v. II. Electro-ionic valves, type Tungar, Raytheon and mercury vapour arc. The last is specially praised for its efficiency and reliability, for voltages 100–500 and currents 1 to 50 A.

Das Glimmlichtrohr Als Gleichrichter von Wechselströmen (Blue-glow valves as A.C. Rectifiers).—G. Seibt. (*E.T.Z.*, 19th July, 1928, pp. 1077–1079.)

General physical principles are discussed, half-wave and full-wave rectification are compared, various types of valve illustrated and their performances compared; and finally improved "Anotrons" (the largest giving 250 mA. at 1,000 v.) are described in which two anodes and a specially shaped cathode improve the efficiency, the second anode reducing the cathode fall by providing the necessary electrons and ions.

The Direct-current Transformer Utilising Thyratron Tubes.—D. C. Prince. (*G.E. Review*, July, 1928, V. 31, pp. 347–350.)

A few years ago, Pliotrons were made to function as "inverters" and thus to complete the process D.C.–A.C.–A.C.–D.C. For power applications, the thyratron (one form of which consists of a mercury-arc rectifier with a grid added to each anode) appears likely to supersede the pliotron inverter, owing to its smaller loss.

Redresseur à Simple Effet ou Redresseur à Double Effet? (Half wave or full wave rectifier?).—A. Vernay. (*Q.S.T. Franç.*, July, 1928, pp. 20–24.)

This investigation ends with the conclusion that the full-wave rectifier is much to be preferred on economic grounds.

Some Experiments on Geiger Ion Counters.—R. D. Bennett. (*Journ. Opt. Soc. Am.*, May, 1928, V. 16, pp. 339–354.)

It is concluded that the counter is a very sensitive instrument for detecting single ions, an only moderately sensitive detector of ultra-violet light because of low efficiency, and that it is primarily a qualitative instrument though of possible quantitative use subject to the difficulty of keeping the sensitivity constant over long periods.

STATIONS, DESIGN AND OPERATION.

MULTICOMMUNICATION GÉNÉRALISÉE PAR TRÈS COURTES ONDES ÉLECTRIQUES (Multiplex communication by very short waves).—A. Turpain. (*Bull. d.l. Soc. Fran. des Élec.*, June, 1928, V. 8, pp. 570–593.)

This paper was read in 1925, but its publication has been delayed on account of patent processes. It outlines a system of telegraphy and telephony on very short waves, generated by very symmetrical thermionic apparatus and propagated along one common non-inductive conductor which may simultaneously serve other purposes.

THE CUPAR RECEIVING STATION OF THE TRANSATLANTIC TELEPHONE SYSTEMS.—(*Engineering*, 24th August, 1928, V. 126, pp. 225–228.)

A technical outline of the whole equipment, with photographs.

POSTES PORTATIFS À ONDES COURTES (Portable short-wave stations).—(*Bull. d.l. Soc. Fran. Radioél.*, April–May, 1928, V. 2, pp. 3–8.)

The apparatus described is designed to be suitable for rough transport and for all climates, and includes military and aircraft sets. Wavelengths vary from 10 to 100 m.; thoriated filament valves are employed for transmission.

TRANSATLANTIC SUCCESS ON 10 METRES: A DESCRIPTION OF THE APPARATUS USED IN SUCCESSFUL TWO-WAY AMATEUR COMMUNICATION.—P. Auschitzky. (*Wireless World*, 15th August, 1928, V. 23, pp. 201–202.)

NOTE ON THE EFFECTIVE HEATING OF CODE TRANSMITTERS.—F. E. Terman. (*Proc. Inst. Rad. Eng.*, June, 1928, V. 16, pp. 802–804.)

Owing to the fact that Morse Code transmission only occupies the transmitter 46.5 per cent. of the time, the average rate of heating is only 46.5 per cent. of that during a long dash; the percentage is still less for fast sending where the times taken for the current to rise and fall are appreciable fractions of the dot-time. Therefore, if suitable protective relays are provided to guard against over-heating by long tuning dashes, etc., a set can be used at twice its normal rating (3½ times for high speeds) if its power supply and other equipment are designed to allow this. The full power could at any rate be used during periods of heavy static or weak signals.

GENERAL PHYSICAL ARTICLES.

PHYSICO-CHEMICAL CONSIDERATIONS IN ASTROPHYSICS.—W. Nernst. (*Journ. Franklin Inst.*, August, 1928, V. 206, pp. 135–142.)

Among the many points of interest in this paper is the light thrown on the objects of the experiments (high potentials from the atmosphere) referred to in the August Abstracts. Nernst's hypothesis, that the source of energy of the sun and other fixed stars lies in radio-active elements which decompose more rapidly and with greater emission of energy than uranium, etc., finds support in the highly penetrating cosmic radiation which he refers to as "Hess-Kolhoerster" radiation, and likens to a very hard Roentgen radiation. He estimates that from 5 to 20 million volts would be necessary for its artificial production, and it is chiefly for this purpose (and for the much sought-after "splitting of the atom") that his three young assistants are repeating, on a gigantic scale, the Franklin kite experiment.

THE PENETRATION OF ULTRAVIOLET LIGHT INTO PURE WATER AND SEA WATER.—E. O. Hulbert. (*Journ. Opt. Soc. Am.*, July, 1928, V. 17, pp. 15–22.)

The transparency of sea water declines rapidly with decreasing wavelength in the ultraviolet, becoming quite small below $\lambda = 3{,}000$ A.U.; thus resembling the transparency of the atmosphere in clear weather, which begins to decrease rapidly at 3,900 A.U. and falls to zero at about 2,900 A.U. Both transparencies thus fall off with decreasing wavelength, very much as the spectral energy of the sun falls off; and the writer suggests that this is no mere coincidence, but that (to put it graphically) sodium chloride remains in the sea and nitrogen in the atmosphere because, in part, they are transparent to the energetic waves of the solar spectrum, whereas other original constituents, opaque to these waves, have been destroyed and dispersed.

A PROPOSED EXPERIMENT ON THE NATURE OF LIGHT.—D. M. Dennison. (*Proc. Nat. Acad. Sci.*, July, 1928, V. 14, pp. 580–581.)

The writer proposes that a beam of high frequency X-rays should be diffracted at a single crystal lattice, and at the positions of two Laue Spots—say of equal intensity—two Geiger ion counters should be placed; the intensity of the beam being so adjusted by means of filters that only a few light quanta fall upon each counter per minute. If the classical wave theory alone governed the transmission of light, the absorptions at the two counters must take place simultaneously, since it is essential to this theory that any group of waves, however faint, arriving at a grating will be diffracted to all the orders of reflection simultaneously. If, however, the dualistic character of light as explained by quantum mechanics is correct, the absorptions at the two counters will be independent and governed only by the laws of probability in such a manner that the *mean* energy arriving at each spot will be equal to that predicted by the wave theory.

ABSOLUTE X-RAY WAVELENGTH MEASUREMENTS.—A. P. R. Wadlund. (*Proc. Nat. Acad. Sci.*, July, 1928, V. 14, pp. 588–591.)

A further development of the work of Compton and Doan on the diffraction of X-rays by a ruled grating.

THE COMPTON EFFECT AND POLARISATION.—P. Lukirsky. (*Nature*, 25th August, 1928, V. 122, pp. 275–276.)

Über das Auftreten von Eigenschwingungen bei Erzwungenen Bewegungen eines Linearen Harmonischen Oszillators (The production of natural oscillations by forced vibrations of a linear harmonic oscillator).—H. Schmidt. (*Zeitschr. f. Phys.*, 28th July, V. 50, pp. 153–160.)

On the Thermodynamic Equilibrium in the Universe.—F. Zwicky. (*Proc. Nat. Acad. Sci.*, July, 1928, V. 14, pp. 592–597.)

On Relaxation of Electric Fields in Kerr Cells and Apparent Lags of the Kerr Effect.—Beams and Lawrence. (*Journ. Franklin Inst.*, August, 1928, V. 206, pp. 169–179.)

The writers conclude from their experiments that there is no evidence for the existence of a lag of the Kerr effect behind rapidly changing electric fields, and explain on other lines the results of previous workers who considered they had found such lag.

Kerr Effect in Water due to High Frequency Radio Waves.—A. Bramley. (*Journ. Franklin Inst.*, August, 1928, V. 206, pp. 151–157.)

Investigations on the index of refraction of water for wavelengths between 3 and 300 cms. have indicated the existence of absorption lines in this region. For examining this electric spectrum of water, the author used a method involving the measurement of the Kerr effect produced by the electromagnetic field of the oscillator. Results showed that the retardations due to the Kerr effect were proportional to the square of the electric induction, and that water has a number of absorption lines in this region which are equally spaced on a frequency scale, the constant difference between the lines being 4×10^{-6} cm. A further experiment proved that the radiation was selectively reflected when its frequency was nearly the same as the natural period present in the water, thus showing analogy to the case of infra-red absorption bands.

Versuche Über die Resonanz der Reststrahlen und der Kürzesten Hertzschen Wellen (Tests on the Resonance of Residual Rays and the Shortest Hertzian Waves).—M. A. Lewitsky. (*Phys. Zeitschr.*, V. 28, No. 23, 1927, pp. 821–825.)

Two experiments to demonstrate the essential similarity of the short electric waves and the long heat waves. A reflection-spectrum from Iceland Spar was reflected from an electrical oscillator-system (formed of small pieces of wire, 0.1 mm. long, glued by Canada-balsam to a glass plate) the reflection being greatest where the heat-ray wavelengths agreed with those of the oscillator (32 and 92μ). Secondly, the oscillator was excited electrically and its radiation was reflected at an Iceland-Spar surface, analysed by a grid and measured by a thermo-element. Here again the strongest reflection was at 32 and 92μ.

Demonstration of Partial Frequencies in Light Waves of Periodically Varying Intensity.—E. Rupp. (*Zeitschr. f. Phys.*, V. 47, 1–2, 1928, pp. 72–88.)

The modulation of a "radio" wave by a wave of another frequency is imitated in the case of a light wave. A light wave of known frequency is modulated by short electric waves (of the order of 50 cms. wavelength) by the use of the Kerr effect, and the presence of partial frequencies is shown by suitable means.

Über den Ursprung des auf der Atomstruktur Beruhenden Magnetismus (The Origin of the Magnetism due to Atomic Structure.)—Kotarô Honda. (*Zeitschr. f. Phys.*, 16th March, 1928, V. 47, pp. 691–701.)

Dia-magnetism is attributed to the outer ("optical") electrons, but para- or ferro-magnetism cannot be explained in this way; they must be due to the very rapidly rotating electrons in the atomic nucleus.

A Suggested Theory of Electric Conduction.—W. H. McCrea. (*Proc. Camb. Phil. Soc.*, July, 1928, V. 24, pp. 438–444.)

It is a well-known characteristic result of Quantum Mechanics that, given two fixed nuclei at a definite distance apart, an electron initially rotating about one of them will, after a finite time, be found rotating about the other. The author investigates the modification of the effect produced by an external electric field, and shows that this effect so modified suggests an explanation of electric conduction in certain circumstances.

Sur la Contraction Gazeuse de l'Hydrogène Soumis à la Décharge Électrique (The gaseous contraction of hydrogen under electric discharge).—R. Delaplace. (*Comptes Rendus*, 23rd July, 1928, V. 187, pp. 225–227.)

This contraction has been attributed to polymerisation of the hydrogen to the form H_3. The author, however, finds no grounds for this, but obtains definite percentages (up to 4.2 per cent.) of carbon monoxide and methane. In the present note he promises to analyse this result, but does not here indicate the origin of the gases which appear.

Die Abhängigkeit des Normalen Kathodenfalles der Glimmentladung von der Gasdichte (The dependence of the normal cathode fall of the glow—Geissler—discharge on the gas pressure).—A. Güntherschulze. (*Zeitschr. f. Phys.*, 4th July, 1928, V. 49, pp. 473–479.)

Textbooks state that the least potential at which the discharge can be maintained on a cold cathode is independent of the gas pressure. The writer shows that while this is approximately true for helium, oxygen, air, etc., nitrogen or hydrogen give a decrease of the order of 100 volts for an increase of pressure from a fraction of a millimeter to about 20 m.

THE STARK EFFECT AT VERY HIGH FIELD.—Toshio Ishida. (*Nature*, 25th August, 1928, V. 122, p. 227.)

APPLICATION DES LOIS DE L'IONISATION A L'ÉTUDE DE LA DÉCHARGE DANS LES GAZ RARIFIÉS (Application of the laws of ionisation to the study of the discharge in rarified gases).—M. Morand. (*Rev. Gén. d. l'Élec.*, 28th July, 1928, V. 24, pp. 150–151.)

ZUR PROBLEM EINER EINHEITLICHEN FELDTHEORIE VON ELEKTRIZITÄT UND GRAVITATION (The problem of a uniform field theory of electricity and gravitation).—L. Infeld. (*Zeitschr. f. Phys.*, 28th July, 1928, V. 50, pp. 137–152.)

The author develops a world geometry leading to a common theory for the two.

ON THE POTENTIAL OF ELECTROMAGNETIC PHENOMENA IN A GRAVITATIONAL FIELD.—E. T. Whittaker. (*Proc. Roy. Soc.*, 1st August, 1928, V. 120, Series A, pp. 1–13.)

SOME EXPERIMENTAL EVIDENCE SUPPORTING THE KINETIC THEORY OF GRAVITATION.—C. F. Brush. (*Journ. Franklin Inst.*, August, 1928, V. 206, pp. 143–149.)

The writer's ether-wave, or energy-shadow, theory of gravitation is supported by the experimental discovery that certain substances (complex silicates) are endowed with persistent heat-generating activity not due to radio-activity; and still more by the latest discovery that such substances exhibiting small, moderate or large generation of heat show comparatively small, moderate or large impairment (respectively) of their gravitational acceleration when compared with normal substances. These experiments are described.

THE INFLUENCE OF GRAVITATION ON ELECTROMAGNETIC PHENOMENA.—E. T. Whittaker. (*Nature*, 30th June, 1928, V. 121, pp. 1022–1024.)

Taken from a lecture to the London Mathematical Society, this article propounds the question " do the effects of the distortion of space " (of the fixed gravitational field) " resemble in any way the effects of a variable dielectric constant and permeability ? " The answer is in the affirmative, though the resemblance is not quite perfect. Among various interesting deductions, the writer points out that an electron at rest in a varying gravitational field will, in general, emit radiation; while (as a natural consequence) an accelerated electron does not necessarily radiate in a gravitational field. This may prove useful in accounting for the behaviour of electrons in atoms.

THE SUGGESTED APPLICATION OF ULTRA-MICRONIC OSCILLATING CIRCUITS TO NEW ETHER DRIFT EXPERIMENTS.—*H. Hamer.* (*Journ. Opt. Soc. Am.*, May, 1928, V. 16, p. 335.)

The great development in the use of oscillating circuits should make it possible to secure now a sensitivity of about one-part in 10^8 at least, and to permit testing the effect of a possible Fitzgerald-Lorentz contraction on the capacity of a parallel plate condenser or on the inductance of the coil of a H.F. oscillating circuit. These can be rotated about different axes in space into the direction of the supposed ether drift. The tests should determine on the classical basis if the ether, whether considered streaming or stationary, is isotropic or not as regards either its permeability or dielectric values.

SUR LES EXPÉRIENCES DE M. ESCLANGON ET LEUR APPLICATION À L'ÉTUDE DES MOUVEMENTS DE L'ÉTHER À PROXIMITÉ DES MASSES MATÉRIELLES (M. Esclangon's Experiments and their application to the study of the movements of the ether near material masses). — – Corps. (*Comptes Rendus*, 14th May, 1928, V. 186, pp. 1351–1353.)

The writer places confidence in these experiments (*Comptes Rendus*, 27th December, 1927) which showed that when reflection takes place at a mass in movement in the medium through which the rays are propagated, the angles of incidence and reflection are not rigorously equal, their sines being proportional to the velocities of the incident and reflected waves; these themselves being the resultants of the true velocity of light and of the velocities of the ether relative to the reflecting surface. He maintains that M. Esclangon has established a positive and clear result, the existence of which is the negation of the Principle of Relativity, since it establishes a discrimination between the directions of space, and opens the possibility of disclosing an absolute movement of the Earth. Interpreted according to the classic theory founded on the hypothesis of a fixed ether, this result gives a value not less than 75 km. per second (and probably much more) for the total velocity of the Earth. Previous observations tended to place the horizontal component of the apparent ether-wind at not more than 9 km. per second, and the writer suggests that the discrepancy is due to the fact that M. Esclangon's results give the mean between the vertical and horizontal components, the former of which is greatly increased at the expense of the latter in the neighbourhood of material atoms. This suggests a difficult extension to the experiments, to determine the vertical component which should be still higher in value.

SOME EXPERIMENTS ON THE AUTO-ELECTRONIC DISCHARGE.—de Bruyne. (*Phil. Mag.* March, 1928, V. 5, pp. 574–580.)

Del Rosario maintains that the " auto-electronic discharge " from cold cathodes is due to residual gases. The author describes experiments from which it is concluded that this is not the case, and that the currents depend on the nature of the cathode and behave in ways analogous to those of thermionic currents.

MOLECULAR SPECTRA IN THE EXTREME INFRA-RED.—Raman and Krishnan. (*Nature*, 25th August, 1928, V. 122, p. 278.)

The Fermi-Dirac Hypothesis of Gas Degeneration and its Applications.—E. S. Bieler. (*Journ. Frank. Inst.*, July, 1928, V. 206, pp. 65–82.)

This review follows partly the lines of the original treatment by Fermi, but the connection between the Fermi-Dirac principle and the de Broglie wave has been taken from a paper by Pauli.

Étude Expérimentale et Théorique de la Variation des Constantes Diélectriques de Quelques Liquides avec la Pression (Variation with pressure of dielectric constants of certain liquids).—L. Cagniard. (*Ann. de Phys.*, May-June, 1928, V. 9, pp. 460–553.)

The Complete Photo-electric Emission from Potassium.—Jessie Butterworth. (*Phil. Mag.*, July, 1928, V. 6, pp. 1–16.)

The author seeks verification, or the opposite, of Dember's assumption of positive photo-electric emission, working on potassium as one of the metals likely to show the phenomenon to the greatest degree. Her tests lead to the conclusion that if the positive effect does occur, it is at least a thousand times smaller than the current which Dember attributed to the emission of positive ions by photo-electric action, *i.e.*, it is less than 10^{-7} times the negative emission from the same surface under the conditions of the experiments. Further results suggest also that potassium has at least two work-functions corresponding to the wavelengths 9,700 A.U.'s and 57,000 A.U.'s, the lower work-function being possessed by "patches" of the surface which under prolonged illumination acquire the greater work-function (corresponding to the shorter wavelength) possessed by the main surface.

MISCELLANEOUS.

Transmission of Information.—R. V. L. Hartley. (*Bell Tech. Journ.*, July, 1928, V. 7, pp. 535–563.)

Sets up a method of quantitative comparison of the capacities of various systems to transmit information. Among other uses, it provides a ready means of checking whether the transmission possibilities of a complicated system can be what they are claimed to be. It can, for example, be applied to various systems of television, as it has already been applied to cable work and picture transmission.

Über die Induktionswirkung von Starkströmen auf Benachbarte Leitungen (The induction effect of power currents on neighbouring conductors).—H. Schiller. (*Arch. f. Elektrot.*, 19th July, 1928, V. 20, pp. 252–263.)

Carrier Systems on Long-distance Telephone Lines.—Affel, Demarest and Green. (*Bell Tech. Journ.*, July, 1928, V. 7, pp. 564–629.)

Describes developments during the past few years which have resulted in improvement.

Carrier-current Control for Street Lighting.—R. R. Cowles. (*Elec. World*, 28th April, 1928, V. 91, pp. 863–866.)

Control is by a 100-watt transmitter (Colpitt circuit) of three optional frequencies, 35,000, 40,000 or 45,000 cycles per second. The system is used in San Francisco.

Die Einphasenkoppelung, Ein Mittel zur Erhöhung der Betriebsicherheit der Hochfrequenz Telephonie auf Leitungen? (Single-phase coupling, a method of increasing the reliability of high-frequency telephony along power lines?).—Dressler and Tätz. (*E.T.Z.*, 26th July, 1928, V. 49, pp. 1101–1103.)

An argument as to the relative advantages of single-phase and two-phase coupling.

Projection of Curves corresponding to Variable Currents.—A. Bartorelli. (*Science Abstracts*, 25th July, 1928, V. 31, p. 579.)

A method depending on the ponderomotive action of a constant magnetic field upon a wire carrying a current, combined with an arrangement of stroboscopic projection.

Versuche zur Erklärung der Staubelectrisierung (Experiments for the Elucidation of Dust-electrification).—H. Israel. (*Zeitschr. f. Tech. Phys.*, No. 8, 1928, pp. 289–293.)

Böning's theory, dividing the process into two parts—the collision effect and the friction effect, the former causing positive charges on the smaller, negative on the larger particles, and the latter causing positive charges on the larger, negative on the smaller particles—is here tested by a long series of tests, using particles of unlike composition. Böning's original tests were made with particles of the same composition, but of differing size, and his theory is confirmed without exception under these conditions; the author shows that it also applies, with certain reservations, to particles of differing composition.

Über den Widerstand von Flugzengantennen und die Dadurch Verursachte Verringerung der Flugleistungen (The resistance due to aircraft aerials and the consequent diminution of flying power).—F. Liebers. (*Luftf. forsch.*, 7th May, 1928, V. 1, pp. 147–152.)

Die Vorzüge des Kurzwellen-verkehrs mit Flugzeugen (The advantages of short-wave communication with aircraft).—H. Fassbender. (*Luftf. forsch.*, 7th May, 1928, V. 1, pp. 122–125.)

One great advantage mentioned is the possibility (long desired) of using fixed aerials. Success in short-wave aircraft wireless is due chiefly to the dipole fixed antenna. Another is the fact that a purely battery-driven transmitter can telegraph 550 km. or more either in the air or after landing.

The writer finds no evidence of the "dead zones" referred to by American short-wave workers—possibly because in transmission from the air the direct wave suffers less attenuation (*cf.* Plendl, March Abstracts, p. 163).

Interference Elimination. (*Elec. Review*, 13th July, 1928, V. 103, p. 66.)

A note on the methods used by the Canadian Government to prevent, or trace and remedy, interference with broadcast reception due to electric power lines (which are practically all overhead).

Sound-proof Rooms, Bell Telephone Laboratories. (*Nature*, 4th August, 1928, V. 122, p. 186.)

Formerly, the walls were deadened with hair, felt and other absorbing materials, but the result was not good. Recent theories of sound absorption have led to the construction described, involving brick walls covered on both sides with hard cement plaster, air spaces, wood and celotex (the new building material made of matted vegetable fibre).

Aircraft Radio Installations.—M. P. Hanson. (*Proc. I. Rad. Eng.*, July, 1928, V. 16. pp. 921–965.)

Deals in a general way with the technical aspects of aircraft (lighter and heavier than air) radio design and installation, and illustrates the trend of recent development. Advantages and disadvantages of various directional radio applications are shown. The good points are admitted of the British airways' system of having the D.F. equipment favourably located on the ground and manned by capable specialists. The American radio beacon system is the most easily applied of all methods from the pilot's point of view.

Bibliography on Aircraft Radio.—Jolliffe and Zandonini. (*Proc. I. Rad. Eng.*, July, 1928, V. 16, pp. 985–999.)

Contractions for Titles of Periodicals.—R. L. Sheppard. (*Nature*, 25th August, 1928, V. 122, pp. 277–278.)

Criticisms of the abbreviations used in the "World List of Scientific Periodicals (1901–1920)."

Radio Communication on Moving Trains. (*Journ. Franklin Inst.*, August, 1928, V. 206, pp. 283–284.)

Describes recent tests, on the Pennsylvania Railroad, on maintaining communication between engine and guard van by wireless, loud speakers being used both for telephonic and code messages. Each train works on a wavelength of its own, so that passing trains do not interfere with each other. One example where the system is of use is afforded by the case of a standing train having to be parted at a grade crossing to allow highway traffic to pass; the driver can be advised by wireless to back so as to permit uncoupling at the right point, to proceed, and then to stop.

Die Zugbeeinflussungsysteme bei den Eisenbahngesellschaften der V.S. Amerika (Train-control systems on the U.S.A. Railways).—A. Kammerer. (*E.T.Z.*, 5th July, 1928, V. 49, pp. 1005–1009.)

The methods fall into two classes, the "continuous" or line-induction and the "intermittent" or point-induction methods. Both are dealt with in this survey.

T.S.F. et Géologie : La Dérive des Continents (Wireless and Geology: the Origin of Continents).—J. Vivié. (*Q.S.T. Fran.*, August, 1928, pp. 25–32.)

A description of the work recently completed on the determination of the difference of longitude between three points of the globe spaced about 120 deg. along the same parallel of latitude—Algiers, Zi Ka Wei and San Diego; secondary points being Greenwich, Paris, Washington, Tokio and Vancouver. Results appear to be accurate to 4 metres in 20,000 kms., and the writer points out that such accuracy will enable us in a few years to see whether the continents are moving relatively to one another, thus testing Wegener's theory that they were originally one large continent.

Les Stations de Signaux Horaires (Time-Signal Stations).—de la Forge. (*Q.S.T. Fran.*, August, 1928, pp. 43–51.)

The present article deals with America and Oceania. Certain errors and omissions in the previous papers (*cf.* July and August Abstracts) are corrected.

Über Elektrische Felder in der Umgebung Lebender Wesen (Electrical Fields in the Neighbourhood of Living Beings).—M. v. Ardenne. (*Zeitschr. f. Tech. Phys.*, No. 8, 1928, pp. 288–289.)

A very sensitive apparatus, including a thermionic voltmeter, and retaining its sensitivity up to frequencies of 200,000 p.s., was used to look for the presence of electrical fields near human beings. Results were positive in the presence of muscle-contractions (as had been found by other workers) but negative for brain-actions. The author, however, suggests that it is just possible that the fields in this latter case have too high a frequency even for this special apparatus; further work is being done to test this possibility.

Frequenzvervielfachung durch Eisenwandler (Frequency multiplication by iron frequency transformers) — Part I. — E. Kramar. (*Zeitschr. f. Hochf. Tech.*, July, 1928, V. 32, pp. 10–15.)

Sur l'Emploi du Démultiplicateur de Fréquence Ferromagnétique comme Multiplicateur de Phases (The use of the ferromagnetic frequency transformer as a phase multiplier).—E. Rouelle. (*Rev. Gén. d. l'Élec.*, 28th July, 1928, V. 24, pp. 151–152.)

The " Ultramicrometer."—J. Obata. (*Journn. Opt. Soc. Am.*, June, 1928, V. 16, pp. 419–432.)

Detailed construction and various examples of application are here given of the instrument referred to in the June Abstracts.

Study of Imperfect Metallic Contacts.—Todesco and Rossi. (*Nature*, 11th August, 1928, V. 122, p. 227.)

Resumé of a paper read before the Italian Academy. Pélabon recently showed that an imperfect contact between two electrodes of the same metal but of different shape may serve for the rectification of oscillating currents, and hence may replace the crystal or thermionic valve detector. The present paper investigates this effect, and points out that steps must be taken to avoid cohesion, which abolishes the rectifying effect.

Conducteurs n'Obéissant pas à la Loi d'Ohm: Les Soupapes Électriques à Contact (Conductors which disobey Ohm's Law: electric contact rectifiers).—L. Dubar. (*Rev. Gén. d. l'Élec.*, 28th July, 1928, V. 24, pp. 153–159.)

The electronic theory of the conductivity of metals is here applied to the solution of various contact-rectifying processes.

The Theory of Contact-detectors: Investigations of Detector Contacts: More about the Crystal Detector Problem.—(*See Ann. d. Phys.*, 10th July, 1928, *Phys. Zeitschr.*, 1st July, 1928.)

Les Symboles Graphiques Internationaux Concernant L'Électrotechnique (The international graphic symbols relating to electrical engineering.)—(*Rev. Gén. de l'Élec.*, 7th July, 1928, V. 24, pp. 11–26.)

A list of symbols adopted by the International Commission for general " power plant " usage (*cf.* July Abstracts).

The National Physical Laboratory, Teddington: Inspection by the General Board.—(*Nature*, 21st July, 1928, V. 122, pp. 112–113.)

An account of the recent annual inspection, with a description of the extensive programme of exhibits illustrating the activities of the laboratory.

Sur la Constante Diélectrique du Benzite (The dielectric constant of benzil).—L. Saint Antoine. (*Comptes Rendus*, 21st May, 1928, V. 186, pp. 1429–1431.)

Benzil ($C_6H_5COCOC_6H_5$) when dissolved in benzine has exceptional electro-optical properties. The author finds that fused benzil has a very high dielectric constant (13.04 at 95 deg.) which varies rapidly with the temperature (it is 12.12 at 120 deg.). To this fact he attributes the marked electro-optical quality.

Experiments on the Space Charge Around a Conductor emitting Corona.—Carrol and Lusignan. (*Journ. Am.I.E.E.*, Dec., 1927, V. 46, pp. 1350–1357.)

In one experiment, using the straight wire and coaxial cylinder arrangement, the cylinder was earthed through a condenser shunted by a D.C. galvanometer. Directly corona is produced by an increasing A.C. voltage, the galvanometer shows a deflection. At first the current passes from cylinder to earth but as the tension increases the effect is reversed. Several other experiments are described, one of these using a straight wire, flat plate and interposed metallic grid.

Les Lignes Électriques en Cables à 132,000 Volts de New York et de Chicago (132,000 volt Cables).—Emanueli. (*Bull. d.l. Soc. Fran. des Élec.*, May, 1928, V. 7, pp. 480–515.)

A full description of the cables themselves, junctions, insulators, etc., fully illustrated. The work was carried out by the Société Pirelli of Milan. 90,000 kVA. is the maximum load.

Luminous Pressure Waves.—(*Journ. Frank. Inst.*, July, 1928, V. 206, p. 111.)

Photography of the phenomena taking place when a cartridge of dynamite is detonated has shown the existence of luminous waves propagated at high speed in the air surrounding the explosive: tests have shown almost certainly that these are not merely reacting gases projected from the explosive, but real pressure waves at such high temperatures that the gas radiates in the visible region of the spectrum.

Über Piezoquarzplatten als Sender und Empfänger Hochfrequenter Akustischer Schwingungen (Piezo-quartz plates as sender and receiver of H.F. acoustic oscillations).—F. W. Hehlgans. (*Ann. d. Phys.* 10th July, 1928, V. 86, pp. 587–627).

Ultrasonics.—R. W. Boyle. (*Science Progress*, July, 1928, V. 23, pp. 75–105.)

A comprehensive survey, which includes the latest work (*cf.* Langevin, July " Abstracts.")

Über die Vorgänge am System Halbleiter-Leiter (The processes in the " Semi-conductor - Conductor " - Johnsen - Rahbek - system).—H. Toby. (*Ann. d. Phys.*, 30th June, 1928, V. 86, pp. 353–392.)

In these investigations, special attention is given to conditions of dryness.

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPAGADO DE ONDOJ.

Velkaj Mezuradoj en Hindujo Koncerne la Mallongonda Stacio PCJJ (Holando).—T. S. Rangachari.

La aŭtoro priskribas mezuradojn en Bangalore, Hindujo, koncerne la Holanda Stacio, PCJJ, je 30–2 metroj.

La cirkvito uzita konsistas el agordita anteno, kun reakcio, konektita senpere al detektoro kaj sekvita de du Malaltfrekvencaj ŝtupoj. La telefona transformatora elmeto estas aplikita al kristalo kaj mikroampermetro. La anteno estas streĉita vertikala fadeno 30-futojn alta, streĉita inter la laborstablo kaj la tegmento interne de la laborejo. Oni faras observadojn je intervaloj de 5 sekundoj dum periodo de 20 minutoj, kaj du rezultaj kurvoj estas publikigitaj montrantaj rapid-periodan velkadon, krom plimalrapida ŝanĝo de l'meza valoro.

Oni diras, ke fazoj de la luno ŝajnas havi nenian efekton ĉe la naturo de velkado.

PROPRECOJ DE CIRKVITOJ.

La Malutilaj Efektoj de Inter-elektroda Kapacito.—M. von Ardenne kaj W. Stoff.

La kapacitoj ĉeestantaj ĉe unuopa ŝtupo estas montritaj, kaj ilia ekvivalenta cirkvito diskutita detale. La efektoj de reakcio de la kradanoda kapacito estas poste pritraktitaj. Ĉi tio kondukas al diskutado pri l'efekto de la reakcio ĉe malsamaj tipoj de amplifikatoroj, plispeciale kun malsamaj tipoj de anod-cirkvita ŝarĝo. La efekto de hazardaj kapacitoj en 4-elektrodaj kaj multoblaj valvoj estas laste konsiderita.

La teorio de l'diskutado estas bone montrita per ekvacioj kaj vektoraj diagramoj.

Grafika Konstrumetodo por Rezistancaj Amplifikatoroj.—W. A. Barclay.

Ĉi tio estas mallonga artikolo en kio grafikaj metodoj estas donitaj por la rapida solvo d l'kvantoj pritraktita en antaŭa artikolo de A. L. M. Sowerby (*E.W. & W.E.*, Aprilo, 1928a), pri "Kalkuladoj por Rezistancaj Amplifikatoroj."

La grafikaj konstruaĵoj estas ilustritaj kaj diskutitaj, ilia teorio estante pliampleksigita de du mallongaj aldonaĵoj.

Kadra Trapenetrebleco ĉe Fero, kaj la Optimuma aera Interspaco ĉe fera Ŝokbobeno kun K. K. Ekscitado.—A. A. Symonds.

Oni faras aludon al Redakcia artikolo (de Februaro, 1928a), kiam oni montris, ke antaŭ kontinukurenta ekscitado, cikla kurvo reprezentanta la alternantajn fluojn devas esti desegnita ĉirkaŭ iu punkto sur la B—H diagramo, donita de la magneta stato de l'fero. Oni poste montras, ke la sola grava kvanto estas la kliniĝo de la pligrava akso de la SB/SH kadro. Mezuradoj de ĉi tiu kvanto estas poste priskribitaj, kun cirkvita diagramo kaj rezultaj tabeloj kaj kurvoj, kiuj estas ankaŭ diskutitaj.

La dua parto de l'artikolo traktas pri l'optimuma aera interspaco ankaŭ pritraktita en la Redakcia artikolo aludita. La kondiĉoj por kombinita fera kaj aera interspaco estas diskutitaj, kaj oni montras, ke la aera interspaco povas esti elektita por doni kiel eble plej bonan mezan valoron, kiu devus esti uzita kiam ajn oni scias, ke la aplikitaj A.K. voltoj varias laŭ amplitudo kaj frekvenco iugrade.

La efekto de hazarda fluo estas ankaŭ diskutita kaj la artikolo finiĝas per ekzemplo pri l'uzado de la kurvoj kaj informoj cititaj por la desegno de difinita ŝoko.

VALVOJ KAJ TERMIONIKO.

Nova Ideo por Detektora Valvo.

Ĉi tiu artikolo pritraktas sugeston ŝuldatan al K. Posthumus (de la Laborejoj de la firmo Phillips).

Oni montras, ke elektronoj forlasas la filamenton kun malsamaj rapidecoj, kaj ke la detektado, aparte de malfortaj signaloj estas efektivigita plejparte de malrapide movantaj elektronoj. Oni sugestas, ke apartigo de l'elektronoj povas esti efektivigita pere de magneta kampo. La malrapide movantaj elektronoj estus defleksitaj ĝis pligranda grado, ol tiuj movantaj plirapide, kaj se ili estus kondukitaj al aparta krado, estus eble multe pliigi la detektajn ecojn de valvo.

HELPA APARATO.

Valv-provilo kun Senpera Montrilo.—M. G. Scroggie.

Simpla kaj rapida metodo estas priskribita por mezuri anodan impedancon, pligrandigan proporcion, kaj komunan konduktancon de ricevaj valvoj. La metodo konsistas, necese, el utiligo de la tensia falo trans rezistanco konektita inter la malaltatensia baterio kaj altatensia negativo, por obteni negativan tension ĉe la krado, kaj el mezurado de la ŝanĝo de anoda kurento naskita de ĉi tiu ŝanĝo de krada tensio.

La principo de la metodo estas diskutita, kaj plena cirkvita diagramo de l'aparato estas donita, kun rimarkigoj pri ĝia utiligo en la praktiko.

Kelkaj Elmetaj Potenco-mezuradoj ĉe Laŭtparolilo Funkciigita per Mova Bobeno.—H. A. Clark kaj N. R. Bligh.

La artikolo priskribas eksperimentojn pri la rezisteco kaj reaktanco de reprezenta laŭtparolilo de la tipo movbobena trans la skalo de aŭdeblaj frekvencoj, kaj kun la laŭtparolilo je ĝia normala funkcia stato kaj kun la diafragmo rigide krampita, tiel ke la akustika elmeto estas malpliigita ĝis nulo.

La mezura metodo uzita estis egalproporcia induktometra ponto, kun telefona detektado super, kaj vibro-galvanometra detektado sub, 200 cikloj. La aparato estas ilustrita diagrame, kaj antaŭzorgoj de funkciado estas diskutitaj.

Rezultkurvoj estas donitaj pri rezisteco kaj pri reaktanco, kun la diafragmo kaj libera kaj krampita, pri l'impedanco de la laŭtparolilo sole, kaj pri la parolilo, transformatoro kaj valvo, k.t.p. La eksperimentaj rezultoj estas diskutitaj, kune kun la efekto de tensio-malpliiga transformatoro, valva impedanco, kaj la efekto de l'valva karakterizo.

La rezultoj malkaŝas diafragman resonancon je ĉirkaŭ 40 cikloj, kun malpliiĝo de elmeto je la plialtaj frekvencoj (ekzemple, pli ol 1000 cikloj), kaŭze de pligrandigita reaktanco.

Aldonaĵo donas ampleksan diskutadon pri l'Ekvacioj de Movo por movbobena laŭtparolilo.

GENERALAJ FIZIKAJ ARTIKOLOJ.

KELKAJ NOVAJ APLIKADOJ DE MALLONGONDA RADIO.—D-ro. J. Taylor kaj D-ro. Wilfrid Taylor.

La aŭtoroj priskribas la utiligon de tre altfrekvencaj (mallongondaj) osciladoj por eksciti lumeton en ege vakuigitaj tuboj je treege plimalaltaj tensioj, ol estas bezonitaj ordinare.

La efekto estis unue eksperimentita de Gutton en Francujo kaj de Kirchner en Germanujo, dum Wood kaj Loomis en Usono utiligis ĝin por eksciti spektrojn en diversaj gasoj.

La aŭtoroj priskribas kaj ilustras ekscitan cirkviton konsistantan el valva generatoro kuplita per fadenaranĝo Lecher'a al malŝarĝa tubo kun eksteraj elektrodoj. La ĝenerala formo de l'malŝarĝoj estas priskribita, kaj la problemo de alta frekvenco diskutita kaj klarigita. La artikolo poste traktas pri malŝarĝoj en mallarĝaj tuboj kaj en bulboj, priskribante la efektojn obtenitajn, ĉi tiuj estante bone ilustritaj per serio de fotografaj platoj.

Oni laste diskutas aplikadojn, kun sugestoj pri la funkciado de valvoj je tre altaj frekvencoj, la naturo de l'tavolo Heaviside, kemiaj efikoj de industria aplikado, kaj la efektoj de vitraĵo, kiel ĉirkaŭaĵo por vakuigitaj bulboj, k.e., valvoj.

DIVERSAĴOJ.

RESUMOJ KAJ ALUDOJ.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

ĈAPITRO EN LA HISTORIO DE RADIO-MEZURADOJ.

Redakcia artikolo (super la ĉefliteroj de Prof. Howe) pritraktanta la fondon antaŭmilitan de la Internacia Scienca Radiotelegrafia Komisiono, kaj mezuradojn pri signalforteco de l'aŭtoro sub la aranĝoj de l'Komisiono.

LIBRO—RECENZO.

Oni donas recenzon de Speciala Raporto No. 6 de la Radio-Esplorada Komitato :—

" Esplorado pri Rotacianta Radio-Signalilo," de R. L. Smith-Rose kaj S. R. Chapman, eldonita de *H.M. Stationery Office*, Londono.

ĈIUJARA VIZITO AL LA NACIA FIZIKA LABOREJO.—Aferoj Interesaj laŭ Senfadena Vidpunkto.

Oni donas mallongan noton pri aferoj interesaj laŭ senfadena vidpunkto, montritaj ĉe l'Nacia Fizika Laborejo, Teddington, dum la ĉiujara vizito je 26a Junio, 1928a.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Loop Permeability in Iron.

To the Editor, E.W. & W.E.

SIR,—In view of correspondence concerning the position of a small hysteresis loop relative to the B—H curve, some further explanation of the first figure of my article on "Loop Permeability "* may be advisable.

In drawing such a loop it should be borne in mind whether the loop is to represent a single small cycle or the effect of an applied alternating E.M.F. The top of a single small loop, which, strictly speaking, will not be a closed curve, will lie near the main curve from which it sprung, but a loop representing events in the iron after a large number of similar small cycles will occupy a different position.

Ewing has investigated such phenomena very thoroughly.† The effect of superposed magnetic cycles, at first large and then gradually reduced after the manner of demagnetising by reversals, is to render the iron almost entirely independent of the previous magnetic history of the piece, the final induction being somewhat higher than that given by the reversal curve for the same constant magnetic force. The change seems due to the violent molecular shaking up, and the effect of very small cycles, though less marked, is also to increase the mean induction.

It is apparent, then, that after a number of cycles have been superposed on an existing induction due to a constant magnetising force, the mean induction will be changed.

---

* See *E.W. & W.E.*, p. 485, September, 1928.

† " Magnetic Qualities of Iron," J. E. Ewing and H. G. Klaussen, *Phil. Trans.*, 1893, pp. 1024–1032.

In the article referred to, this induction, the D.C. component, is as stated, taken as being defined by the reversal curve, and the loops are drawn about it accordingly.

A. A. SYMONDS.

To the Editor, E.W. & W.E.

SIR,—There is not a wide difference between μ' at 90∼ as found by Mr. Symonds and μ' at 500∼ as found by the writer (*W.W.*, July 14th, 1926). Clearly μ' does not decrease rapidly with increase in f. At $f = 40{,}000$∼ the initial μ' was found to be 270 for 0.0015″ iron. After saturation the value was reduced to 160 (*W.W.*, Nov. 24th, 1926).

The values of δB used by Mr. Symonds and myself are in excess of those found in a modern intervalve transformer. For example, at $f = 90$∼, secondary peak voltage = 15, ratio $3.5/_1$, primary inductance 100 henrys. δB is about 10 lines per sq. cm. Above and below 90∼ δB would decrease and increase respectively.

Since μ' varies with δB (see Fig. 2a) the primary reactance ωL_1 at any value of f will depend upon the signal strength. Thus at frequencies below 100∼ where the valve resistance is comparable with ωL_1, the amplification will vary with the signal strength. In a complete receiver with inter and output transformers, the proportion of acoustic energy below 100∼ will therefore be greater for strong than for moderate signals (apart from the sensitivity of the ear).

In many cases the valve feed current is carried by the primary of the output transformer to the L.S. This causes a serious fall in L_1 especially when L.S.5A valves are used at high voltage. It can be obviated by using the familiar choke-condenser-feed system, but in this case the transformer iron is worked on a main and not on a subsidiary loop—assuming the iron to be demagnetised initially. With a moderate magnetisation, the main hysteresis loop introduces harmonics. Whether these are as large as those with the subsidiary loop can only be decided by measurement. I have not noticed much difference when using a loud speaker, but the harmonics may be too small to be readily perceptible by ear.

I should like to indicate a drawing error in Figs. 1 of the three articles mentioned above. The subsidiary loop should be wholly to the left of the B-H curve. As shown it is symmetrical, but not scientific.

N. W. MCLACHLAN.

London.
3rd September, 1928.

Output Power Measurements on a M.C. Loud Speaker.

To the Editor, E.W. & W.E.

SIR,—It is not clear from Messrs. Clark and Bligh's article in your September issue that the resonance at 40 ∼ is due to the diaphragm vibrating *as a whole on its oiled-silk support.* The resonant frequency can be reduced well below 40 ∼ by using a suitable grade of thin rubber. In the *Wireless World*, 8th August, 1928, I described experiments showing a support resonance at 50 ∼ due to rubberised silk. There was also a resonance due to the diaphragm alone (apart from its support) at 200 ∼. I see that Messrs. C. and B. found no diaphragm resonance, but this may have been due to the frequency gaps in their curves. The Editor of the *W.W.* has several of my articles in his possession dealing with various aspects of this problem which will be published in due course. In particular there is the case of a small diaphragm on a leather surround. This has a pronounced and distressing resonance at 70 ∼. Although the coil current at 4,000 ∼ is only about *a fifth* of that at 400 ∼, there is a tendency to accentuate the upper register. This can be attributed to the mechanical acoustical properties of the diaphragm, presumably some form of resonance apart from the surround.

Fig. 3c for low frequencies is incorrect since the condenser effect of the moving coil has been omitted. The equivalent circuits together with the theory—minus the mathematics which were beyond the scope of the journal—have been published in the *W.W.* from 30th March, 1927, onwards. Also vector diagrams are given in my handbook *Loud Speakers*, pp. 67–70.

The values of motional resistance from 100 ∼ upwards seem to be unduly high. At 250 ∼ the value is 4 ohms. Taking a gap density of 8,000 lines per sq. cm. and assuming the diaphragm to be a flat rigid disc, I find the acoustic radiation resistance to be of the order 0.4 ohm. The difference between their figure and mine seems to be too large for frictional and other losses.

With a coil of 1,000 turns I have found the motional resistance by experiment to be 73 ohms at 250 ∼, corresponding to an efficiency of 6.5 per cent. By calculation, using the equivalent rigid disc, the radiation resistance is of the order 70 ohms. A similar agreement between theory and practice has been found at higher frequencies. As a consequence, I am inclined to doubt the high value of efficiency, namely, 16 per cent. at 100 ∼ given by Messrs. C. and B. Incidentally I calculate the resistance of their coil at rest as 15 ohms, whereas from Fig. 5 curve B, the value exceeds 18 ohms, which seems peculiar.

At the higher frequencies, *e.g.*, 5,000 ∼, since a coil movement of a few millionths of an inch corresponds to a loud sound, special precautions must be taken to ensure that the coil does not move.

A point of interest is the effect of the field coil on the moving coil. Since the coils are coupled electromagnetically, the inductance and resistance of the M.C. alters according as the field coil is open or closed. When closed through a battery, the iron is magnetised by the A.C. in the moving coil, and therefore works round a subsidiary loop. The M.C. inductance varies slightly with the battery current. Since the coil moves in a steady field with an A.C. field superposed, currents of double frequency, etc., are induced. An investigation by an oscillograph indicated that these alien frequencies were of no importance for a coil of 1,000 turns used to give moderate output.

N. W. MCLACHLAN.

London.
5th September, 1928.

Some Recent Patents.

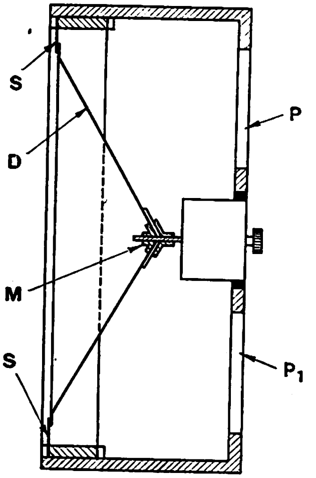
The following abstracts are prepared with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each.

LOUD SPEAKERS.

(*Application date, 11th January,* 1927. *No.* 288,713.)

A conical diaphragm *D* is made of hot-press paper about 0.02 millimetre thickness and weighing about 0.015 gramme per square centimetre. From a circle of 8⅝ inches radius, a sector is cut of 60 degrees, giving a cone-base of 13¾ inches diameter and a projected area of slightly less than 1,000 sq. cms. This is then glued to a circular surround *S* of thin paper, such as is commonly used for charcoal sketches. The terminal condition at the periphery is arranged to reduce reflection and therefore diaphragm resonance to a minimum.

Such a diaphragm is stated to "break-up" at all frequencies above about 80 cycles, so that the effective area in vibration is less than the actual area of the diaphragm. Moreover, as the applied frequencies increase from 80 to 6,000 cycles, the effective area in vibration decreases progressively, so that in combination with the varying sensitivity of the reed the overall response remains uniform from 150 cycles upwards, instead of tending to favour the higher frequencies as usual.



The driving elements (not shown), including the reed and its connections *M* to the diaphragm, are designed to have a natural frequency of between 2,500 and 3,500 cycles per second, whilst the natural frequency of the whole vibrating system (including the diaphragm) lies between 700 and 1,100 cycles. The diaphragm is housed in a box which acts as a baffle, as shown, the front being covered with silk, and the back formed with apertures *P*, P_1 to reduce undesirable resonance effects.

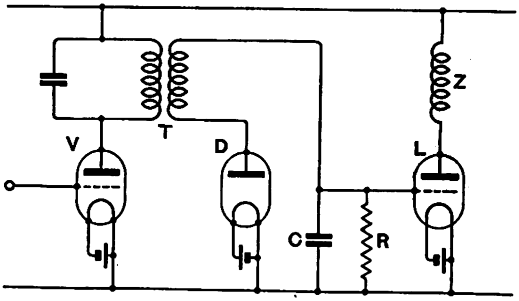
Patent issued to N. W. McLachlan.

VALVE TRANSMITTERS.

(*Convention date* (*Germany*), *29th March,* 1927. *No.* 287,903.)

In high-powered transmission it is desirable to provide a load-compensating circuit during "spacing" periods, or at other times when the aerial oscillations are cut out or reduced, so as to prevent dangerous surges of voltage likely to injure the installation. With this object in view, a special compensating valve is arranged so that its conductivity varies with the conditions of the keying-circuit.

As shown in the figure, the compensating-valve *L* is shunted across the main transmitting-valve *V* in series with a choke *Z* or other suitable resistance. The grid circuit comprises a condenser *C*, leak resistance *R*, and a diode or rectifying valve *D* coupled to a resonant circuit *T* in the plate of the transmitter. Under these conditions, the greater the energy flowing in the circuit *T*, the greater will be the negative bias thrown by the rectifier *D* on the grid condenser *C*, and the less the resultant conductivity of the compensating valve *L*, so that it takes practically no load. As the aerial oscillations decrease, the negative bias on *C* is reduced, so that the conductivity of the valve *L* increases and it comes automatically into action to maintain the overall load constant.

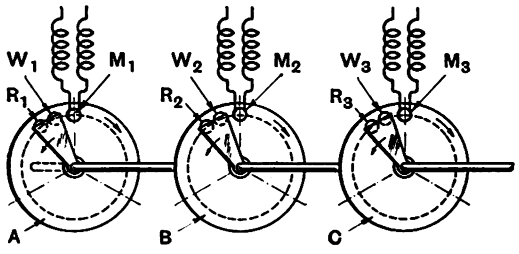


Patent issued to the Telefunken Co., Ltd.

TELEVISION APPARATUS.

(*Application date, 26th January,* 1927. *No.* 292,632.)

In order to speed-up the process of exploring a scene or object to be televised, a number of different sections are explored simultaneously, and magnetic records are taken on a rotating disc in a manner similar to that of the well-known Telegraphone. The records are subsequently read at a higher speed than that at which they were originally recorded.



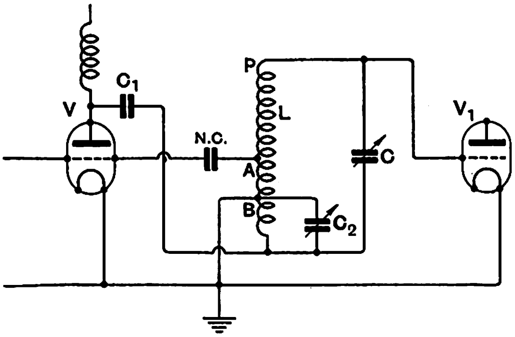
As shown in the figure, three magnetic discs *A*, *B*, *C* are mounted on a common shaft. Light-modulated signals from the object or scene to be televised are then fed through coils associated with magnetic recorders M_1, M_2, M_3, so that a transient "magnetic image" of the signals is impressed upon the discs. Pick-up or receiving devices R_1, R_2, R_3, adapted to convert the impressed images into corresponding current-variations, are so mounted in conjunction with the discs *A*, *B*, *C* that they can traverse the discs in the opposite direction to the recorders *M* and at a higher speed. Mounted close to each receiver *R* is a "wipe-out" device W_1, W_2 W_3 adapted to erase the transient image previously recorded, so as to leave the disc free to receive the next impression. In operation the pick-up or receiving devices *R* are rotated at three times the speed of the recorders *M*, giving a corresponding gain in the speed of the original exploration. As soon as the record on disc *A* has been finished, the disc *B* is switched into circuit, and is then followed by disc *C*. Meanwhile, a fresh record is being traced on the first disc.

Patent issued to Television, Ltd., and J. L. Baird.

NEUTRALISING CAPACITY EFFECTS.

(*Application date, 4th April*, 1927. *No.* 292,716.)

In order to stabilise a valve amplifier over a wide range of working frequencies an additional capacity is inserted between the main oscillatory circuit and a point at a steady or earth potential in such a way as to make all the associated capacities symmetrical about this point. As shown in the figure, the valve *V* is coupled to the valve V_1 through a condenser C_1 connected to the lower end of the tuned circuit *L C*. The upper end *P* of the inductance *L* is taken to the grid of the second valve, whilst a neutralising condenser *N C* is tapped off from an intermediate point *A* on to the grid of the first valve. The point *B* is connected to the common filament circuit.



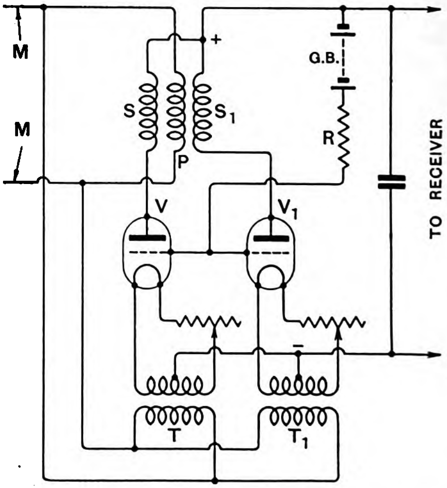
In these circumstances the capacities to earth are unsymmetrical about the point *B*. The grid-filament capacity of the valve V_1 is shunted across the large portion *P B* of the inductance *L*, and in general the capacity to earth of the portion *P B* of the inductance *L* is greater than that between *B* and the lower end of the inductance; so that the potential difference between the points *A* and *B* is greater than if a true balance existed. Also the ratio of the currents in the part *A B* and the part from *B* to the end of the inductance increases as the tuning condenser *C* is reduced, necessitating a continual readjustment of the neutralising condenser *N C*. The insertion of an additional condenser C_2 across the point *B* and the lower end of the inductance *L* is found to remove this lack of symmetry and the difficulties consequent thereon.

Patent issued to W. J. Brown and the Metropolitan Vickers Co., Ltd.

A.C. MAINS UNIT.

(*Convention date* (*U.S.A.*), 31*st March*, 1926. *No.* 268,797.)

A pair of thermionic valves is used to rectify the current supply from A.C. mains *M*, a biasing potential on the grids serving automatically to smooth the pulsating output. The transformer *P* across the mains *M* has two secondary windings *S*, S_1, the common or neutral point *P* constituting the positive terminal of the rectified current. The free ends of the two secondaries are connected to the plates of two three-electrode valves, the common point of the filament forming the negative terminal of the rectified current. The filaments of the valves are energised by two transformers *T*, T_1, shunted across the main supply leads *M*, as shown.



The grid of each valve is biased with a positive voltage approximately equal to the D.C. voltage required, derived from a battery *GB* in series with a resistance *R*. Under these conditions, when the rectified voltage wave drops below the required D.C. voltage, each grid will become positive, relatively to the filament, and the effective impedance and voltage drop across the valve rectifiers will be reduced. Conversely when the output wave rises above the desired D.C. voltage, the valve impedance is increased, so that the action automatically tends to smooth-out any variations above or below the steady voltage to be fed to the wireless receiver.

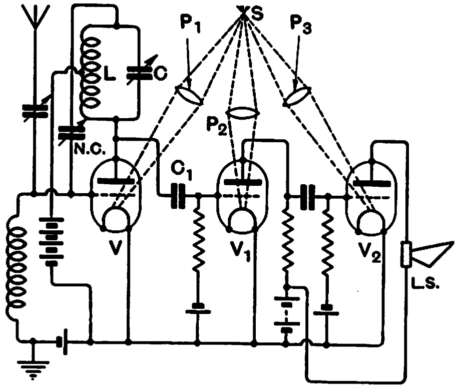
Patent issued to the Metropolitan Vickers Co., Ltd.

PHOTO-ELECTRIC AMPLIFIERS.

(*Application date*, 29*th March*, 1927. *No.* 293,107.)

Photo-electric cells provided with a control grid are used as a substitute for three-electrode thermionic valves, the electron stream being produced by the action of light upon a sensitive cathode. The source of light is preferably passed through a rotating drum or moving screen, so that the cathode. stream is rendered intermittent at a definite frequency, a feature which facilitates subsequent amplification.

As shown in the figure, incoming signals are applied between the control grid and sensitised cathode of the first amplifier V, which is coupled through a tuned circuit L, C and condenser C_1 to a similar amplifier V_1. The latter in turn is resistance-coupled to a cell V_2 feeding a loud speaker LS. The high-tension supply is taken through a mid-point tapping on the coil L, a neutralising condenser NC balancing the inter-electrode capacity. All the amplifier cathodes are rendered active by a common light-source S through focusing lenses P_1, P_2, P_3, suitable means being provided for protecting them from fortuitous light-rays. The rotating drum or interrupter (not shown) is interposed between the source S and the focusing lenses. Such photo-electric amplifiers may be used in combination with thermionic valves of standard type, the overall response being stated to be strictly proportional to the applied signal energy.



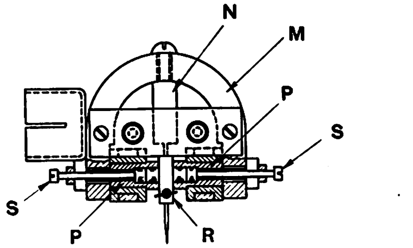
Patent issued to W. S. Smith and N. W. McLachlan.

GRAMOPHONE PICK-UPS.

(*Application date*, 7*th April*, 1927. *No.* 293,483.)

In order to reproduce faithfully from a gramophone record it is necessary that the reed and needle should both be suitably damped, so that they are effectively held from any uncontrolled movement. In the pick-up device shown in the figure, a permanent magnet M is fitted with pole-pieces P, between which depends a metal reed R, carrying the record needle and anchored to a suitable support N.

Each pole-piece P is of tubular formation and accommodates an adjusting screw S, by means of which a small piece of rubber can be pressed gently against the reed R, so as to centre the latter and impose a damping or restraining action. This does not prevent any movement imparted to the needle by the record, but will effectively damp-out any promiscuous or uncontrolled lateral vibration. The rubber dampers, being located close to the fulcrum of the reed, allow the needle maximum leverage, and so ensure a highly sensitive operation.



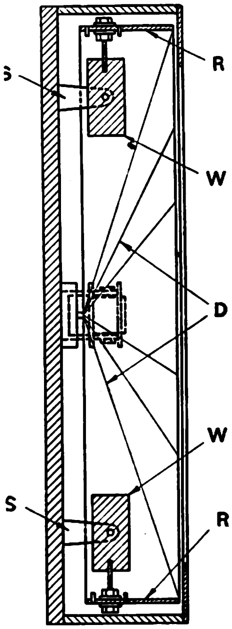
Patent issued to L. H. Pearson and C. Marshall.

LOUD SPEAKERS.

(*Application date*, 7*th July*, 1927. *No.* 293,200.)

When the edge of a conical or similar diaphragm is rigidly clamped, there is a tendency for the reed or other driving means to be forced out of proper adjustment, either by temperature changes or by any sudden blow or shock. In order to avoid this, the diaphragm D is attached to a cylindrical ring R of cardboard, which, in turn, is loaded with weights W secured at intervals around it. The weights are balanced upon pivotal supports S.

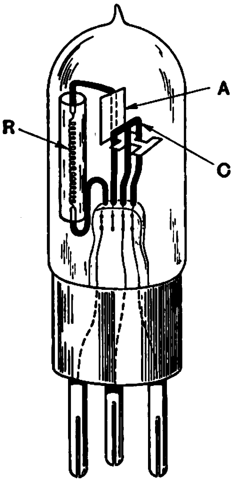
In such an arrangement the diaphragm is free to take up its own position under temperature changes without throwing any strain upon the reed. Also the diaphragm and balance weights can move relatively to the containing box or case if the loud speaker as a whole is subjected to accidental shock. Finally, since the weights are balanced, the parts are not affected if the position of the containing case is altered. The total mass of the supporting means is such that the natural free period of vibration of the diaphragm and its supports is below audibility.



Patent issued to E. V. Mackintosh and C. French, trading as Celestion Radio Co.

GAS-FILLED RECTIFIERS.

(*Application date, 2nd March,* 1927. *No.* 293,365.)



In order to maintain a constant current through a gas-filled discharge tube used for rectifying, in spite of fluctuations in the supply voltage, a special resistance *R* is incorporated in series with the anode *A* and is mounted inside the bulb. A low-temperature incandescent cathode of the Wehnelt type is preferably used.

The ballasting resistance *R* consists of an iron or tungsten wire, which in an atmosphere of argon has the property of passing a constant current within certain limits of voltage variation. In order to prevent it from taking part in the actual discharge between cathode and anode, and so suffering gradual disintegration, the resistance is screened by a small tube of insulating material, such as glass, located behind the anode proper.

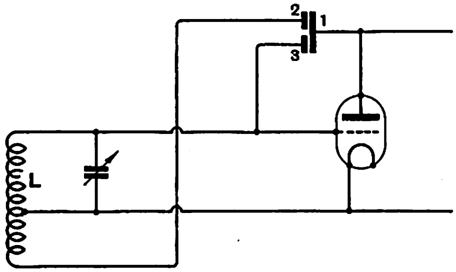
Patent issued to H. Wade (N. V. Philips Glowlamp Co.)

BALANCING CONDENSERS.

(*Application date, 26th April,* 1927. *No.* 293,926.)

The circuit illustrates a receiving loop-aerial *L* having one end connected to the grid of an amplifier, an intermediate tapping to the filament, and the other end connected to the plate through the special balancing and reaction-control condenser shown. The latter consists of a movable plate 1 co-operating with two fixed plates, 2, 3, the arrangement being such that as the capacity between 1 and 2 increases, that between 1 and 3 decreases, and *vice versa.*

It will be seen that the capacity between the plates 1 and 3 is in parallel with, and is therefore added to the inter-electrode grid-plate capacity to be balanced. The arrangement gives a smooth reaction control, since the capacity between plates 1 and 3 is added to the inherent grid-plate capacity of the valve just at the point where that capacity may be insufficient to secure a stabilised balance.



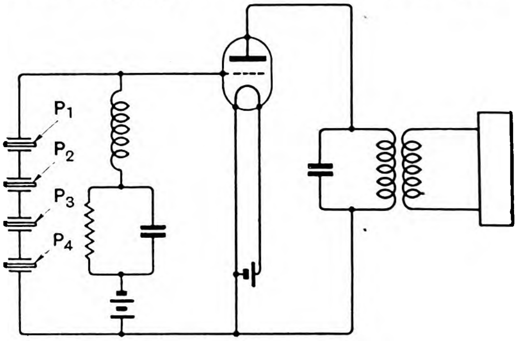
Patent issued to Burndept Wireless, Ltd., and C. F. Phillips.

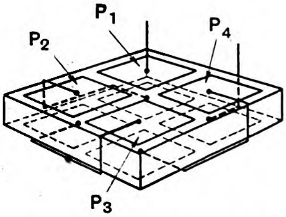
PIEZO-CONTROLLED OSCILLATORS.

(*Application date, 31st December,* 1927. *No.* 294,061.)

Relates to means whereby the power output of a crystal-controlled valve oscillator can be greatly increased without danger of fracturing the crystal, whilst at the same time eliminating any fluctuations in the fundamental frequency due to temperature variations. When the oscillator *O* is in steady operation, the voltage between grid and filament converges towards a certain definite value, depending upon the applied plate tension and the amplification factor of the valve. In practice it is found that for grid voltages beyond a few hundred volts there is danger of the crystal being ruptured.

According to the invention, four separate crystals, P_1 to P_4, having substantially the same fundamental frequency, or related in harmonic ratio, are connected in series across the grid and filament, so that the effective voltage across each individual crystal is only one-fourth the full drop. The output power can therefore be increased proportionally without exceeding the safety factor. The first two crystals should be cut perpendicular to, and the last two parallel with a natural face of the mother crystal, so that they have temperature coefficients of opposite sign. The effect of any overall temperature variation is therefore balanced out. Instead of using separate crystals, a single large crystal may be fitted with a series of separate electrodes, as shown in the lower figure, the lower plate of one pair being connected to the upper plate of the next pair, so that the four pairs are in series relation.





Patent issued to Standard Telephones and Cables, Ltd.

579

EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. V. NOVEMBER, 1928. No. 62.

Editorials.

Some Fundamental Definitions.

IN the March and April numbers we discussed certain difficulties which arise in defining Potential Difference and Electromotive Force in alternating current circuits. In the present number we publish a paper by Mr. Wilmotte dealing with the same subject from a slightly different point of view. It is satisfactory to note that Mr. Wilmotte's conclusions agree almost entirely with our own; even in the few questions of detail where there is an apparent disagreement, with one exception, this is due to misunderstanding. We commend a careful perusal of Mr. Wilmotte's article to all those of our readers who desire to obtain clear conceptions on these fundamental terms of electrical science. In discussing his Fig. 3, Mr. Wilmotte says: "The reader will have noticed that the conduction current was said to be *practically* the same in all parts. If it were absolutely the same, as stated by Professor Howe, no charge could accumulate in the wire."

What we actually said was "the current is necessarily the same at every part of the ring *once the steady state has been established*" (see page 177). Surely this infers that the current is not the same at every part while the charges are accumulating. In discussing this same problem, Mr. Wilmotte says: "I do not understand Professor Howe's simple expression for the value of the potential difference."

Here we have to confess that the simple expression was wrong. The electromotive forces induced in the two halves of the ring, at the moment when the pole passed through the plane of the coil would not be proportional to the angles subtended as we assumed, in our simple numerical example, but, as Mr. Wilmotte says, they could be obtained by a more or less laborious analysis. Mr. Wilmotte's statement that "in connecting a voltmeter along wires *POQ* to find the potential difference between the points *P* and *Q*, Professor Howe is neglecting the *E.M.F.* induced by the current in the circle of wire *A*" would be a relevant criticism if the current in the ring were changing; we simplified the problem by assuming that the current had reached a steady state.

There is only one portion of Mr. Wilmotte's paper with which we do not entirely agree, and that is his arbitrary division of a circuit into several parts in dealing with self and mutual inductance. He rather disarms criticism by saying that "it is not intended to consider whether this is practically possible or not."

We should prefer to keep to things which are practically possible or, at least, conceivable.

What is Straight-line Amplification?

THIS question was recently asked and answered on the front page of a leading daily paper in connection with an advertisement for a well-known make of gramophone. The meaning attached to the term was, however, entirely different from the meaning associated with it in the mind of every radio and telephone engineer. To the latter the term is associated with a constant ratio of amplification over a certain range of frequencies, so that if the amplification is plotted to a base of frequency, a horizontal straight line is obtained. In the advertisement in question, the principle of straight-line amplification is stated to consist in replacing the rounded bends in the tone-arm of a gramophone by plane corners which are supposed to reflect the sound waves in the same way as a mirror would reflect a beam of light. The beams or rays of sound are thus reflected in an orderly *straight-line* way along the tone-arm as compared with distorting cross-reflections in previous tone-arms with nicely rounded corners. As the science of acoustics, especially in its application to the gramophone, is of ever-increasing interest to radio engineers, we need make no apology for referring to this matter in some detail. The analogy between light and sound must be used with great caution because of the enormous difference between the wavelengths in the two cases. A reflector to be effective must have dimensions of the same order at least as the wavelength concerned. In light we are dealing with wavelengths of less than a thousandth of a millimetre, whereas the wavelength of a high note with a frequency of 1,000 is over a foot, and that of a low note with a frequency of 50 is over twenty feet. To be at all effective as a reflector of sound, the reflecting surface must therefore be something of the order of twenty feet in diameter as a minimum; to act as a really efficient reflector it would have to be much larger; to be equivalent to a mirror the size of a pin's head, the reflector of sound would have to be made with a diameter of about two miles. We may leave our readers, therefore, to imagine how effective the sound reflection will be at the flattened corners of a gramophone tone-arm, and whether the sound waves are likely to be more or less distorted by such a departure from the smooth curves of the ordinary tone-arm.

It is amusing to note that this enunciation of the principle of straight-line amplification is hailed as "an important advance in scientific research." We wonder if it was originally evolved as a *jeu d'esprit* by some member of the scientific staff of the firm concerned and has fallen accidentally into the hands of some member of the advertising department who did not know enough of the elements of acoustics to see the joke.

Transmitting Amateurs in Conference.

A photograph taken at the Annual Convention of the Radio Society of Great Britain, which was held on September 29th last at the Institution of Electrical Engineers.

Surges in Eliminator Smoothing Circuits.

By A. G. Warren, M.Sc., M.I.E.E., F.Inst.P.

Summary.

WHEN changes occur in the H.T. potential applied to a receiving set through a smoothing circuit, surges are liable to take place, giving rise to voltages which may, in certain circumstances, be much in excess of the normal working potential. Risk of breakdown is thus incurred. The problem is here examined when the supply is D.C., though in some cases, which are indicated, the results are equally applicable to a rectified A.C. supply.

The surges are most serious at switching on and switching off, especially if this switching is done with the filaments not alight, or the set not connected. For this reason the main H.T. supply should only be switched with the set connected and the filaments alight.

For adequate smoothing (and regulation, when used with rectified A.C.) it is necessary to maintain reasonably high values for chokes and condensers; for all normal voltages, requirements are met if the product LC is of the order of 200 microfarad-henrys (*e.g.*, 4-microfarad condensers used in conjunction with a 50-henry choke, or 2-microfarad condensers with a 100-henry choke).

It is shown that a smoothing circuit which may be perfect on one set may give rise to bad surges upon another.

For a set requiring a definite anode current it is shown that reducing the size of the condensers and increasing the value of the choke, reduces the surge at switching on but increases the surge at switching off, and *vice versa*. There are therefore optimum values for these components. Rules are given enabling the condensers and choke to be so proportioned to the load that the normal working voltage is not exceeded either at make or break.

Introduction.

Recent advances in receiving sets have called for output valves capable of dealing with a considerable amount of power. For the supply of energy to these valves the eliminator is deservedly popular. When well designed it requires practically no attention and it is extremely economical in use.

It is, however, since the demand for more power has arisen that one has heard at all frequently of condenser breakdown. Such breakdowns suggest that surge voltages may occur in the smoothing circuit in excess of the test voltage of the condensers. The object of the present article is to examine how such excess potentials arise, and how they may be reduced by proper adjustment of the values of the components in accordance with the duty which the eliminator is called upon to fulfil. Such surges may occur both upon switching on and switching off, and their magnitudes are affected by the methods adopted in effecting those operations. The results given below are applicable to an eliminator used on D.C. mains; in some cases they are also applicable to an A.C. eliminator; those cases are indicated.

Surge on Switching On.

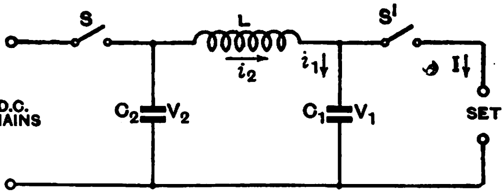


Fig. 1.

If we consider the circuit of Fig. 1 we see that when the switch S is closed (S' being already closed), the condenser C_2 is almost instantaneously charged to the potential of the mains. At the same time a current i_2 starts to grow through the inductance L. We may neglect the resistance of L—in any case its effect is small. Now an inductance of L henrys is one which requires L volts to cause a current through it to grow at the rate of 1 ampere per second. At any time the rate at which the current i_2 is growing, in amperes per second, is obtained by dividing $V_2 - V_1$ by L. Expressed mathematically this simple relation is

$$V_2 - V_1 = L\frac{di_2}{dt} \quad \ldots \quad \ldots \quad (1)$$

If, for instance, L is 50 henrys, and the mains voltage is 200, the current i_2 starts to grow at the rate of 4 amperes per second. At the end of one thousandth of a second the current will be 4 mA. Most of this current will be flowing into the condenser C_1, causing its voltage V_1 to rise. As V_1 rises, the rate of growth of i_2 diminishes and the current I through the set increases.

A condenser of C farads is one which requires C amperes to flow into it to cause its voltage to rise at the rate of one volt per second. At any time the rate at which the voltage V_1 is increasing is obtained by dividing i_1 by C_1. Expressed mathematically this relation is

$$i_1 = C_1 \frac{dV_1}{dt} \quad \ldots \quad \ldots \quad (2)$$

Thus, when the switch is first closed the potential of C_1 is not growing at all, but at the end of the first one-thousandth of a second, if $i_1 = 4$ mA. and C_1 is 4 microfarads, the potential is growing at the rate of 1,000 volts per second.

As the voltage V_1 grows, the current I grows in a manner depending upon the characteristic of the power valve. The equation

$$I = f(V_1) \quad \ldots \quad \ldots \quad (3)$$

is a mathematical way of stating that this characteristic is known.

We have also the obvious simple relation

$$i_2 = i_1 + I \quad \ldots \quad \ldots \quad (4)$$

The equations (1) to (4) are sufficient to determine the subsequent variations of voltage and current. The integration of these equations in general terms is impossible unless equation (3) can be expressed in a definite mathematical form. If, however, the characteristic is known, practical solutions of the equations may be obtained by "tabular integration." It is not proposed to detail the method here. But the results are of importance and will be dealt with carefully.

The first case we shall consider is the closing of the switch S with S' open or the filaments not alight. In these circumstances the whole of the current i_2 is expended in charging the condenser C_1. The current i_2 continues to grow until V_1 becomes equal to V_2; but the current i_2 does not then die out, *it only ceases to grow.* Current still flows and V_1 rises still further, the current i_2 diminishing. This process continues until V_1 becomes equal to $2V_2$, when i_2 becomes zero; thence i_2 reverses and V_1 falls. The voltage oscillates between zero and twice the voltage of the mains; the oscillation is only damped out slowly by the losses in the choke. The periodicity of this oscillation is determined by the product LC_1. For the case cited ($C = 4\,\mu$F., $L = 50$ H.) the frequency is about 11.3 cycles per second; the oscillation is illustrated in Fig. 2.

The magnitude of this surge may be expressed very simply mathematically. By the time the voltage V_1 has ceased rising, suppose the total quantity of electricity which has flowed through L to C_1 is q. Then the energy thus supplied from the mains is V_2q. But the energy stored in the condenser is $\frac{1}{2}V_1q$. Hence $V_1 = 2V_2$.

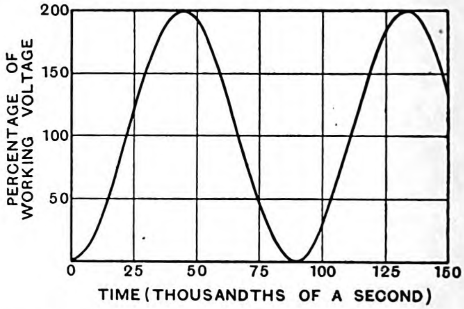


Fig. 2.—Surge at make.—Filaments not alight.

In practice the switch S should not be closed unless the set is connected (S' closed) and the filaments are alight. We now consider the effect upon the surge of the energy taken by the set. In the results which follow it has been assumed that the current I is proportional to $V_1^{3/2}$. This relation approximates to practice closely enough to give results of reasonable accuracy.

As in the case already considered, when the switch S is closed, the current i_2 grows, raising the potential of the condenser C_1. As this potential V_1 increases, the current I, taken by the set, increases. It cannot be rigidly demonstrated without the use of fairly advanced mathematics that, in consequence, the extent to which the voltage rises is necessarily less than twice the voltage of the mains. But it can easily be shown to be extremely probable. The voltage V_1 will cease rising when the current i_1 diminishes to zero, i_2 will then still have a positive value equal to the current being taken by the set at the highest potential V_1; there is, therefore, still energy associated with the inductance; call this energy x. The rate at which current flows through the set increases with the voltage, and hence, if q_1 is the total quantity of electricity which has flowed through it, it is reasonable to assume that the average voltage at which it has flowed is greater than one-half the maximum. In other words, the energy supplied to the set exceeds $\frac{1}{2}V_1q_1$ by some amount which we will call y. If the quantity of electricity then stored in the condenser is q_2, its energy is $\frac{1}{2}V_1q_2$. We must then have :—Energy supplied by mains = energy stored in inductance + energy stored in condenser + energy used by set, or

$$V_2(q_1 + q_2) = x + \tfrac{1}{2}V_1q_2 + \tfrac{1}{2}V_1q_1 + y,$$

whence it follows that V_1 is less than $2V_2$.

A particular example of such a surge oscillation determined by tabular integration of equations (1) to (4) is illustrated in Fig. 3. This curve has been worked out for an eliminator having condensers each of value 4 μF. with a choke of 50 H. (quite normal values) when used with a set requiring 40 mA. at 200 volts. It is seen that the maximum pressure at switching on is about 244 volts—an excess over the mains voltage of 22 per cent., which need cause little alarm. If, however, this same eliminator is used on a set requiring only 10 mA. at 200 volts, the surge at switching on is more serious. It is illustrated in Fig. 4. The maximum voltage is now 336 or 68 per cent. above the working value.

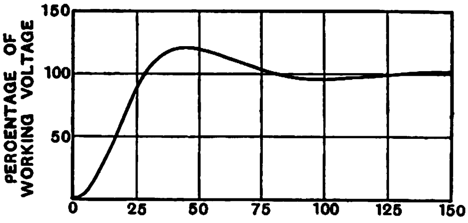


Fig. 3.

$V = 100$, $I = 5$ mA., $C = 1\mu$F., $L = 200$ H.
$V = 200$, $I = 20$ mA., $C = 2\mu$F., $L = 100$ H.
$V = 400$, $I = 80$ mA., $C = 4\mu$F., $L = 50$ H., etc.
Surge at make—$I/CV = 0.05$, $LI/V = 10$.

The question immediately arises whether, for this smaller current, different values for the condenser and choke will, while still being satisfactory from the point of view of regulation (when used on rectified A.C.) and freedom from ripple, give rise to a smaller surge at make. A brief examination of the fundamental equations (1) to (4) shows that the curves already drawn are applicable to other cases than those for which they have been calculated. Thus, if we imagine all currents to be reduced to one quarter, the equations will be satisfied by exactly similar variations of the voltage if we imagine C reduced to one quarter and L increased four times, the product LC being maintained constant. (The product in this case is 200 microfarad-henrys. With such a value for the LC product, smoothing is efficient. When used with rectified A.C., regulation is better the higher the value of C, but is satisfactory so long as the current taken by the set does not exceed 15 mA. per μF. per 100 V.)

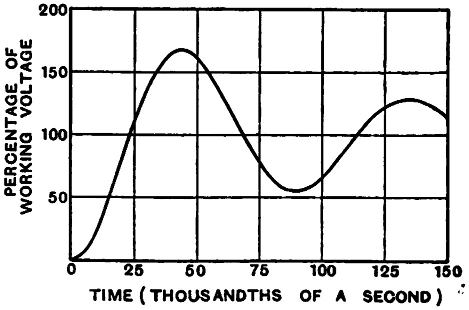


Fig. 4.

$V = 100$, $I = 2.5$ mA., $C = 2\mu$F., $L = 100$ H.
$V = 200$, $I = 10$ mA., $C = 4\mu$F., $L = 50$ H.
$V = 400$, $I = 40$ mA., $C = 8\mu$F., $L = 25$ H., etc.
Surge at make—$I/CV = 0.0125$, $LI/V = 2.5$.

Fig. 3 therefore not only represents the variation of voltage when $I = 40$ mA., $C = 4$ μF., $L = 50$ H., but also the variation when $I = 10$ mA., $C = 1$ μF., $L = 200$ H., and for all cases where $I/C = 10$ mA. per μF. and $LI = 2{,}000$ mA.H. Similarly, Fig. 4 applies to all cases where $I/C = 2.5$ mA./μF. and $LI = 500$ mA.H.

Again, if we imagine all voltages and currents doubled, equations (1) to (4) are similarly satisfied (the voltages being expressed as multiples of the working voltage), so that Fig. 3 is applicable to all cases in which $I/CV = 0.05$, and $LI/V = 10$, the units being milliamperes, microfarads, volts and henrys: *e.g.*, $V = 200$ V, $I = 10$ mA., $C = 1$ μF., $L = 200$ H.; $V = 100$ V, $I = 10$ mA., $C = 2$ μF., $L = 100$ H.; $V = 300$ V, $I = 60$ mA., $C = 4$ μF., $L = 50$ H., etc.

Figs. 5 and 6 are drawn for higher current to capacity ratios. Fig. 5 shows the voltage rising steadily to its normal working value without exceeding it. One set of conditions satisfying this curve is $V = 200$ V, $I = 80$ mA., $C = 4$ μF., $L = 50$ H. The same curve would also represent the conditions $V = 200$ V, $I = 40$ mA., $C = 2$ μF., $L = 100$ H. Fig. 6 represents a still slower rise to the normal working value.

We see, therefore, that it is possible by adjusting the values of L and C to eliminate any surge voltages at make greater than the normal working voltage.

Surge at Switching Off.

We saw that on switching on the high tension supply the surge voltage could never exceed the normal working voltage by more than 100 per cent. This limitation does not exist when the circuit is broken.

The instant before the circuit is broken we have no current flowing into the condenser C_1 (*i.e.*, $i_1 = 0$), and the current i_2 through the inductance is equal to the load current I. Suppose that the first operation in switching off is to open the switch S' (which it should not be). The whole current i_2 ($= I$) is diverted from the set into the condenser C_1, which commences to rise rapidly in potential, continuing to do so until the current through the inductance has fallen to zero. By then, not only has this condenser received the whole energy previously stored in the inductance but also the extra energy received from the mains. The larger L and I and the smaller C, the greater will be the voltage to which the condenser C_1 is raised. From this point the voltage falls, energy flowing back into the mains; the process continues as an oscillation.

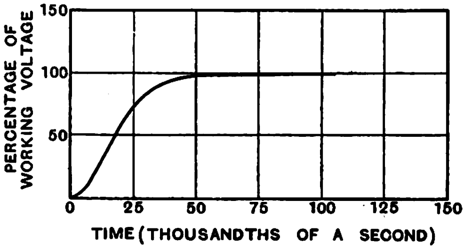


Fig. 5.

$V = 100$, $I = 10$ mA., $C = 1\mu$F., $L = 200$ H.
$V = 200$, $I = 40$ mA., $C = 2\mu$F., $L = 100$ H.
$V = 400$, $I = 160$ mA., $C = 4\mu$F., $L = 50$ H., etc.
Make—$I/CV = 0.1$, $LI/V = 20$.

The maximum voltage attained is easily calculated. Immediately before opening S' the energy stored in the inductance is $\frac{1}{2}LI^2$, and in the condenser $\frac{1}{2}q_1V_1$ (where q_1 is its charge). As the current i_2 is falling to zero, a quantity of electricity which we may call q_2 flows from the mains and becomes stored in the condenser C_1. By the time i_2 has fallen to zero, imagine the condenser C_1 to have risen in potential to V. Then we must have

$$\tfrac{1}{2}LI^2 + \tfrac{1}{2}q_1V_1 + V_2q_2 = \tfrac{1}{2}(q_1 + q_2)V \quad \ldots (5)$$

where $q_1 = C_1V_1$ and $q_2 = C_1V$ .. (6)

Substituting from (6) in (5) we get a simple quadratic equation for V. If $I = 40$ mA., $V_2 = 200$ V, $C = 4$ μF., and $L = 50$ H., we find that the roots of the equation are $V = 341.4$ or 58.6; that is to say, the oscillation is between those limits. If, however, $I = 40$ mA., $V_2 = 200$ V, $C = 1$ μF., and $L = 200$ H., we find $V = 765.7$ or -365.7. Here the rise to 283 per cent. above the normal working voltage is very serious.

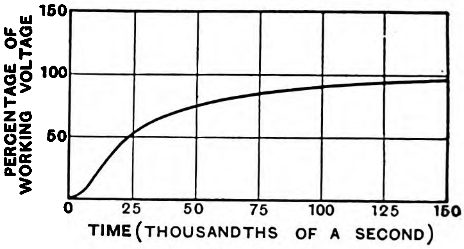


Fig. 6.

$V = 100$, $I = 10$ mA., $C = 0.5\mu$F., $L = 400$ H.
$V = 200$, $I = 40$ mA., $C = 1\mu$F., $L = 200$ H.
$V = 400$, $I = 160$ mA., $C = 2\mu$F., $L = 100$ H., etc.
Make—$I/CV = 0.2$, $LI/V = 40$.

Conditions would not be so bad if both switches S and S' could be opened simultaneously. In this case the current I would, as before, be diverted into the condenser C_1, but the current i_2 would diminish more rapidly because V_2 falls as V_1 rises. It is easy to show that if $I = 40$ mA., $V_2 = 200$ V, $C_1 = C_2 = 4$ μF., and $L = 50$ H., that the maximum voltage would be 300; but that if $I = 40$ mA., $V_2 = 200$ V, $C_1 = C_2 = 1$ μF., and $L = 200$ H., the maximum voltage would be 600, again a very serious value. These surges would occur to the same extent in a set operated from rectified A.C.

If, however, the set is shut down, as it should be, by first opening the switch S, rise of voltage of C_1 cannot take place. The current I continues to flow, first at the value it had before the switch was opened, the energy coming almost entirely from the condenser C_2, which falls in potential. Now if the inductance L is large and the capacity C_2 small, C_2 will not only fall to zero but may acquire quite a large negative potential by the time the current i_2 ceases. Before this stage is reached the condenser C_1 has taken over the greater share of the load current and its potential is falling rapidly. The current i_2, having fallen to zero, reverses and C_2 begins to charge up again positively at the expense of C_1, whose potential falls to zero and reverses. As the potential V_1 falls to zero, the current I vanishes and remains zero so long as V_1 is negative, the oscillation then being "free." The oscillation continues, energy being sapped from it whenever the potential V_1 is positive. In some respects the oscillation resembles that just considered, but its amplitude is less because of the energy which is taken by the set. The fundamental equations (1) to (4) are also applicable to this case, together with the equation

$$i_2 = -C_2 \frac{dV_2}{dt} \quad \cdots \quad \cdots \quad (7)$$

Employing tabular integration for these equations, the curves given in Figs. 7, 8 and 9 have been obtained. Fig. 7 shows the characteristics just described, the maximum negative voltage being 1.93 times the normal working potential—a serious value. (If S' were opened instead of S, the surge potential would be 3.83 times the working potential.) For larger condensers and a smaller inductance the maximum negative potential is only 0.51 of the normal working voltage—Fig. 8. (In this case if S' were opened before S there would be a surge potential 2.41 times the working voltage.)

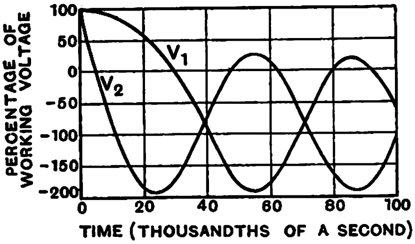


Fig. 7.

$V = 100$, $I =$ 10 mA., $C = 0.5\mu$F., L = 400 H.
$V = 200$, $I =$ 40 mA., $C = 1\mu$F., $L = 200$ H.
$V = 400$, $I = 160$ mA., $C = 2\mu$F., $L = 100$ H., etc.
Surge at break—$I/CV = 0.2$, $LI/V = 40$.

In the case illustrated in Fig. 9 the voltages oscillate without reversing, except to a very small extent after a considerable time interval. These curves are obviously equally applicable to a set working from D.C. mains or from rectified A.C.

Conclusion.

It is clear that in no case should voltage be switched on to, or off of, a smoothing circuit (except gradually) unless the circuit is connected to the set with the valve filaments fully alight. That point being established we may review briefly, but carefully, the results obtained above. We have seen that, in some cases, switching may be effected without any voltages occurring in excess of the normal working potential, *e.g.*, see Figs. 6 and 9. But the conditions of Fig. 6 are the same as those of Fig. 7; there is no excess voltage at make, but at break a voltage 1.93 times the working voltage occurs. Again, the conditions of Fig. 9 are the same as those of Fig. 3; there is no excess voltage at break but a voltage 1.22 times the working voltage occurs at make. Were the current only 10 mA. with this filter, no surge would occur at break, but on switching on there would be a rise of potential to 1.68 times the working voltage (Fig. 4).

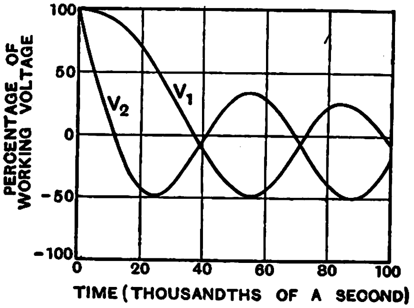


Fig. 8.

$V = 100$, $I =$ 10 mA., $C = 1\mu$F., $L = 200$ H.
$V = 200$, $I =$ 40 mA., $C = 2\mu$F., $L = 100$ H.
$V = 400$, $I = 160$ mA., $C = 4\mu$F., $L = 50$ H., etc.
Break—$I/CV = 0.1$, $LI/V = 20$.

We see that reducing the size of the condensers and increasing the value of the choke reduces the surge at make, but increases the surge at break, and *vice versa*. The following table, which has been prepared from calculated results, shows, however, that it is possible to choose the values of the components of the smoothing circuit so that no voltage in excess of the working voltage occurs, either at make or break.

TABLE

(FOR SMOOTHING CIRCUITS $LC = 200\ \mu$F.H.).

I/CV.	LI/V.	Maximum voltages expressed as multiple of normal.	
		Make.	Break.
0	0	2	1
.0125	2.5	1.68	1
.05	10	1.22	1
.1	20	1	1
.125	25	1	1
.2	40	1	1.93

From this table we see that it is desirable to arrange for I/CV to be between 0.1 and 0.125. If there is any doubt about the value of the load current it is better to have I/CV too low rather than too high. Since the regulation will be better on rectified A.C. if I/CV is low we may definitely adopt the values $I/CV = 0.1$ mA./μF.V. and $LI/V = 20$ mA.H./V. At 200 volts the current per microfarad would be 20 mA. This is satisfactory from the point of view of regulation. The curves relating to this series of circuits are given in Figs. 5 and 8.

Of course, surges may *theoretically* be eliminated, whatever the values of the components of the smoothing circuit, if the voltage is applied slowly through a potentiometer. This, however, is not simple to arrange in an economical manner. Nor is it really effective—it takes no account of those momentary interruptions of the supply (such as the change of a feeder) which, short as they are, are sufficiently long to puncture a condenser.

To conclude, a few examples may be given. The chosen values may be conveniently stated as $C = 10I/V$ and $L = 20V/I$, the units being microfarads, henrys, volts and milliamperes.

(*a*) Smoothing circuit for 50 mA. at 250 volts:

$$C = 2\ \mu\text{F.},\quad L = 100\ \text{H.}$$

(*b*) Circuit for 60 mA. at 150 volts:

$$C = 4\ \mu\text{F.},\quad \text{L} = 50\ \text{H.}$$

(*c*) Circuit for 10 mA. at 100 volts:

$$C = 1\ \mu\text{F.},\quad L = 200\ \text{H.}$$

The variety of these circuits is not surprising considering the different duties they have to perform. The surprising fact is that the same components are often expected to behave well under widely varying conditions. Considering circuit (*c*), which man be looked upon as representative of the load used by small horn speakers, the capacity suggested is less than that usually employed and the inductance greater. The reasons are not far to seek. Eliminators are more commonly used with rectified A.C., and a large condenser is employed to reduce the voltage drop. But this is quite unnecessary, since any voltage can be obtained with a transformer. A large condenser may do no harm, since the surge at make is limited by the rectifying system. But it is more desirable to follow the growing practice of designing the rectifying and smoothing elements as separate units (see, for example, *Wireless World*, February 22nd and 29th, 1928) so that the set is more or less independent of the nature of the supply. Again, the amateur is inclined when using rectified A.C. to connect in any and every condenser he may have available, with the object of improving the smoothing. This is quite unnecessary. With an LC product of 200 μF.H., hum should not be heard in the speaker. If a hum is heard, it is not due to lack of smoothing, as is indicated by the fact that increasing the condenser C_2 will often make the hum more pronounced. Hum in these circumstances may be due to induction. It is more likely to be due to a high frequency oscillation (modulated at 50 or 100 cycles) set up in the transformer leads by the sudden rushes of current through the rectifying valve as it becomes conducting. These oscillations may be prevented by short-circuiting them at the transformer with a 0.1 μF. condenser.

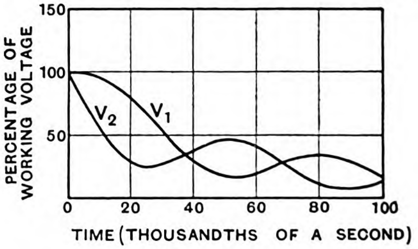


Fig. 9.

$V = 100$, $I = 5$ mA., $C = 1\mu$F., $L = 200$ H.
$V = 200$, $I = 20$ mA., $C = 2\mu$F., $L = 100$ H.
$V = 400$, $I = 80$ mA., $C = 4\mu$F., $L = 50$ H., etc.
Break—$I/CV = 0.05$, $LI/V = 10$.

Some Fundamental Definitions.

By Raymond M. Wilmotte, B.A., A.M.I.E.E.

Potential Difference and E.M.F.

IN two recent numbers* of *E.W. & W.E.* Professor Howe has given a very lucid account of some difficulties underlying the ordinary meanings of potential difference and E.M.F. On the main issue I am in complete agreement with Professor Howe, but on certain questions of detail I cannot follow him. It is true that definitions of quantities are purely matters of convenience, and two separate sets of definitions may be independently correct; they will be so so long as they are self-consistent. The definitions of P.D. and E.M.F., when related to alternating current, do not appear to have been rigorously defined. On the other hand there are certain accepted conventions about them.

Thus, in the well-known problem of a magnet moving along the axis of a circle of wire, it is generally recognised that there is an E.M.F. induced in the wire, that a current flows; yet from symmetry there can be no potential difference between any two points of the wire.

Any definition of P.D. and E.M.F. must not only be mathematically rigorous but also submit to the generally accepted conventions of the terms. Below is an explanation of the manner in which, I believe, suitable definitions can be reached.

Among the fundamental units of electricity the definitions of potential difference and E.M.F. lead to remarkably vague and diverse opinions. There appears to be no difficulty about the definitions of charge, current and other quantities. The necessity for a rigorous definition of potential difference will be admitted when it is realised that it is directly involved in a number of other definitions of fundamental importance. These are impedance, capacity, self-inductance, and mutual inductance. The last two are of special importance, for all the electrical units are obtained experimentally from them. The ohm, the farad, the ampere, the volt, etc., are all fundamentally dependent on a self or a mutual inductance.

I am not quite sure of the exact definitions which Professor Howe gives to potential difference and E.M.F. Although fundamentally they appear to coincide with my own view, the result he gives in one example considered does not appear to agree with my conception of his meaning.

There are two points which Professor Howe has not mentioned, though they are so intimately connected with the problem that in my opinion their omission leaves important parts of the problem unexplained. These are the absolute necessity of the existence of capacity effects in order that potential differences may be formed, and that there are two very distinct meanings of E.M.F. depending on whether the term is applied to self-inductance or mutual inductance.

It is difficult to deal with the later steps of the argument without stating the first steps. As I shall deal with matter rather more mathematically and from a slightly different standpoint, perhaps it will not be out of place to repeat some of the fundamental principles explained by Professor Howe.

The difference in standpoint may be brought out by the fact that Professor Howe is always considering closed circuits, whereas in the following the whole explanation is based on portions of circuits. Professor Howe's standpoint is to a great extent illusory, as it is not possible to speak of the E.M.F. or potential difference between two points in a circuit without considering each portion of the circuit separately.

There is no difficulty in defining potential in electrostatics, when there is no variation of the field with time. The potential at a point is then defined as the work done in bringing a unit charge from infinity up to that point, assuming that this unit charge does not disturb the field. In this definition it is not necessary to specify the path which the charge is to take, for the work done is independent of this path. When, however, there are in the system currents varying with time, the value of the potential difference calculated from the above definition will materially differ with the path taken by unit charge, so that this simple definition breaks down.

---

* March and April, 1928.

This phenomenon is numerically stated in Faraday's experimental law. This law states that the E.M.F. induced in a circuit is proportional to the rate of change of the number of magnetic lines of force threading that circuit. Suppose we bring a unit charge from infinity (which we shall conveniently represent by the point O Fig. 1.) to the point A by the path OMA, a certain amount of work will be done. If now we return to O by the path ANO, the total quantity of work in going from O to A and back will not be zero, but will be equal to the rate of change of the total number of lines of force threading the circuit $OMAN$. The work done in going from O to A along the path OMA will therefore be different from the work done along the path ONA. The question arises, which is to be chosen ?

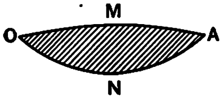


Fig. 1.

The simplest method would evidently be to choose the path along which no E.M.F. due to magnetic induction were induced, and we should now enquire how to find such a path.

For this purpose we shall introduce a conception familiar to mathematicians but looked at askance by all other scientists. This is Vector Potential. This quantity is such that a certain operation involving differentiation with regard to space gives the value of the magnetic field, and differentiation with regard to time gives electric intensity due to the magnetic field. Thus, if H_x, H_y, H_z are the components of the magnetic field, E_x, E_y, E_z, the components of that part of the electric intensity which is due to the magnetic field, and A_x, A_y, A_z, the components of the vector potential, we can write.

$$H_x = \frac{\delta A_z}{\delta y} - \frac{\delta A_y}{\delta z} \quad \dots \quad \dots \quad (1)$$

$$H_y = \frac{\delta A_x}{\delta z} - \frac{\delta A_z}{\delta x} \quad \dots \quad \dots \quad (2)$$

$$H_z = \frac{\delta A_y}{\delta x} - \frac{\delta A_x}{\delta y} \quad \dots \quad \dots \quad (3)$$

$$E_x = - \mu \frac{\delta A_x}{\delta t} \quad \dots \quad \dots \quad (4)$$

$$E_y = - \mu \frac{\delta A_y}{\delta t} \quad \dots \quad \dots \quad (5)$$

$$E_z = - \mu \frac{\delta A_z}{\delta t} \quad \dots \quad \dots \quad (6)$$

Equations (1) to (3) are usually written vectorially in the form $H = \text{curl}\, A$.

It happens that there are many expressions for the vector potential which will fit these equations. We are at liberty to impose arbitrarily other suitable condition to suit our convenience.* The condition generally imposed makes vector potential directly determinable from the conduction currents of the system. Just as the scalar potential, ϕ, known in electrostatics is derivable from the distribution of charges, q, in the system by the expression

$$\phi = \Sigma\left(\frac{q}{r}\right)^{\|} \quad \dots \quad \dots \quad (7)$$

so the vector potential is obtained from the conduction currents, of components i_x, i_y, i_z, by the expressions

$$A_x = \frac{1}{c^2} \Sigma\left(\frac{i_x}{r}\right)^{\|\ddagger} \quad \dots \quad \dots \quad (8)$$

$$A_y = \frac{1}{c^2} \Sigma\left(\frac{i_y}{r}\right) \quad \dots \quad \dots \quad (9)$$

$$A_z = \frac{1}{c^2} \Sigma\left(\frac{i_z}{r}\right) \quad \dots \quad \dots \quad (10)$$

where c, the velocity of the light, enters in the expression to keep units consistent.

Let us consider an elementary length of wire, say, of length δx, parallel to the X-axis, situated in the field. If the currents vary

---

* This is similar to the solution of an ordinary differential equation, where there are always one or more constants which we adjust to suit our particular purpose.

|| There is a further effect which it may sometimes be necessary to take into account at high frequencies. A charge or current will produce a scalar or vector potential at a point, but the potential takes a certain time to reach that point, since it travels with the velocity of light. If r is the distance, the potential arrives at the point considered with a time lag of r/c.

‡ When there are present magnetic poles of intensity I, the full expression is

$$A = \Sigma\left(\frac{i + \text{curl}\, I}{r}\right).$$

with time, *e.g.*, alternating currents, charges are set up in the system.*

The electric intensity in the element of wire can only be due to the distribution of charges in the system and the way in which these are varying, that is to say, due to the charges and the currents. The contribution to the electric intensity due to the current we can state in terms of the vector potential introduced above. If ϕ is the potential due to the charges, we have that the electric intensity in the element considered is due to the terms

$$\frac{\partial \phi}{\partial x}\delta x \text{ and } \mu \frac{\partial A_x}{\partial t}\delta x$$

this must be balanced by the ohmic drop, so finally,

$$\mu \frac{\partial A_x}{\partial t}\delta x + \frac{\partial \phi}{\partial x}\delta x + Ri_x\delta x = 0 \quad (11)$$

where R is the resistance per unit length, and all the terms are measured in electrostatic units.

This equation is of the highest importance and is the basis of the present argument. The first term, which we shall in future call the "$\partial A/\partial t$ term" represents the E.M.F. induced according to Faraday's law, and is derived directly from the conduction currents only of the system. The second term, which will be called the "$\partial \phi/\partial x$ term" is derived directly from the distribution of charges alone and is not dependent on the conduction current (except in so far as variations in conduction current are the cause of the existence of charges).

If we calculated the sum of the $\partial A/\partial t$ terms between two points A and B, we would find that the result depended on the path taken. In the case of the $\partial \phi/\partial x$ term, which gives the electrostatic value of potential difference, this is, of course, not so, the difference in the value between the two points A and B being independent of the path taken. It would be convenient, therefore, to define potential difference in terms of the scalar potential ϕ alone. Let us examine if this will agree with the usual conception of the meaning of potential difference. What is the usual conception? It is that the potential difference between two points in a circuit is the ohmic drop plus the E.M.F. induced between those two points. The exact meaning of this E.M.F. is usually left undefined, but it is agreed that it contains at any rate the E.M.F. induced, in accordance with Faraday's law, in the wire joining the two points of the circuit. That is, it is the sum of all the $\partial A/\partial t$ terms added along the wire joining the two points considered.

If the E.M.F. is defined solely as this term, the potential difference is the sum of such terms as $\mu \frac{\partial A_x}{\partial t}\delta x + Ri_x\delta x$ added along the circuit joining the two points considered.

From Equation (11) we see that this is the same as the sum of $-\partial \phi/\partial x$ terms. This can be evaluated from the charge distribution alone, without considering the effects of the currents and the magnetic fields attached to them. This is a particularly satisfactory result, as such a definition of potential difference between two points will be independent of the path taken to go from one point to the other.

We therefore define potential difference at any instant as follows: We assume that all the electric charges of the system are suddenly stopped. By so doing the currents and the magnetic fields disappear together with that part of the electric intensity due to them. The potential difference between two points at that instant, then, is the work done in taking a unit charge from one point to the other. The value obtained will, of course, be independent of the path taken.

It will be seen, therefore, that for a potential difference to exist, there must be an accumulation of charges. Now these charges can only accumulate owing to variations in the conduction currents, which phenomenon is synonymous with capacity effects. This will be considered more fully later.

In order to illustrate this definition let us take the famous problem of a circle of wire A, Fig. 2. Let us suppose that another circle B (shown dotted) carrying alternating current is held above it. From symmetry there can be no potential difference between any two points on the wire A, yet there is an E.M.F. induced and this E.M.F. can be readily calculated. Now, the distribution of electric charge on such a system must be

---

* Charges are formed when more conduction current enters a certain portion of a conductor than leaves it, or *vice versa*. We can write for the charge q in an element of wire parallel to the X-axis,

$$q = -\int \frac{di_x}{dx}dt$$

symmetrical, so that, according to our definition, there can be no potential difference between any two points on the wire A : the E.M.F. induced* is therefore balanced by the ohmic drop alone.

Up to this point I believe that the views expressed coincide with Professor Howe's, but in the next step, when the wires are not symmetrically above each other (Fig. 3), I do not understand Professor Howe's simple expression for the value of the potential difference. Let us consider this case.

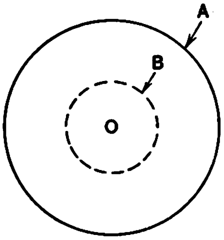


Fig. 2.

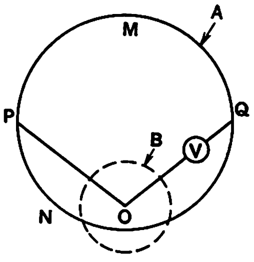


Fig. 3.

We are dealing with low frequencies. The value of the $\partial A/\partial t$ term is very different for different parts of the wire A, as will be readily seen by calculating the value of A for different parts of the wire from Equations (8) to (10), assuming that the current in the wire B is the same in all parts of the wire. We know experimentally that this is true ; we also know that the current in the wire A is practically the same in all parts, so that the variation of ohmic drop along this wire is negligible. From Equation (11) we see that the difference between the ohmic drop and the E.M.F. (the E.M.F. corresponds to the $\partial A/\partial t$ terms) must be borne by the $\partial\phi/\partial x$ terms.

The physical meaning of this is that charges are set up in the various parts of the wire, so that in all parts the value of the sum of the $\partial A/\partial t$ and the $\partial\phi/\partial x$ terms is practically constant and exactly equal to the ohmic drop. Without very careful analysis, however, it is not possible to say exactly how the charges are distributed and, therefore, what is the distribution of potential along the wire A. We know that the ohmic drop is uniform, but cannot obtain a knowledge of the E.M.F. distribution except by a more or less laborious analysis.

Professor Howe stated that the E.M.F. along the wire PMQ was proportional to the angle subtended by that arc at this centre O of the wire B, which seems to indicate that his conception of E.M.F. is different to that explained above. Moreover, in connecting a voltmeter along wires POQ to find the potential difference between the points P and Q, Professor Howe is neglecting the E.M.F. induced by the current in the circle of wire A.

The reader will have noticed that the conduction current in the circle of wire A was said to be *practically* the same in all parts. If it were absolutely the same, as stated by Professor Howe, no charge could accumulate in the wire and there would be no potential difference between any two points of it. At low frequencies the variation of current from point to point of the wire may be small, but it will increase considerably as the frequency rises.

We have only considered the meaning of E.M.F. and potential difference when the whole configuration is known. In many cases it is convenient to divide a system into two or more parts, consider each separately, and take account of the reaction of one on the other. This important consideration, which shows a difference in the definition of E.M.F. when referred to self-inductance and mutual inductance, was not mentioned by Professor Howe. The most obvious example of such a case is that of a transmitting antenna and the receiving antennæ. They all form a single system, though the different parts of it may be thousands of miles apart. The problem is attacked by considering separately each antenna subjected to the reactions due to the other antennæ. In such a case the common meaning of E.M.F. induced from one antenna on the others does not simply consist of the $\partial A/\partial t$ terms, which only takes account of the part of the electric intensity due to the magnetic field, but also the $\partial\phi/\partial x$ terms of Equation (11) which takes account of the part of the electric intensity due to the charge distribution on the distant antennæ. In fact the E.M.F. induced in an element of length is taken as the sum of the $\partial A/\partial t$ and the

---

* This includes the back E.M.F. due to self-induction as well as that due to the current flowing in the wire.

$\partial\phi/\partial x$ terms, which is usually called the electric intensity.

We can obviously bring the antennæ closer and closer together without affecting the above definitions. Eventually, when they are very close together, the reaction of one on the other is commonly called mutual induction, but the E.M.F. induced by mutual induction is the sum of the $\partial A/\partial t$ and the $\partial\phi/\partial x$ terms, while the E.M.F. induced by self-induction, that is by the action of one portion of the system on itself, consists only of the $\partial A/\partial t$ terms as obtained above (*see* Equation 11).

This difference in the meaning of E.M.F. is forced on us when we separate a system into two or more parts, because as soon as we do this, we consider each part under the action of the fields due to the others and we do not analyse these fields into the two terms corresponding to $\partial A/\partial t$ and $\partial\phi/\partial x$.

We may even go still further and consider a simple circuit arbitrarily divided into several parts to each of which the argument of the antennæ will still apply.

This will produce a deviation from the definition of instantaneous potential difference given above. Since, when a system is arbitrarily divided into sections, the part of the electric intensity which is due to the charge distribution of one section on another is included in the E.M.F., it must not appear in the potential difference, otherwise, it would be taken into account twice over. The definition of potential difference between two points is therefore altered to the work done by a unit charge in going from one point to the other against the forces caused by the distribution of charges on the section of the circuit under consideration only at the required instant.

Impedance.

Having now defined potential difference, there is no great difficulty in defining the impedance of a piece of apparatus. It is actually the ratio of the potential difference across it and the conduction current flowing in it, so long as no E.M.F. is induced within the apparatus from the external circuits. There is a difficulty when the current is not constant in amplitude in different parts of the apparatus. In such cases several values for the impedance are obtainable, and it must be specified where the current is measured.

In the general case with sinusoidal currents the potential difference is not in phase with the current, so that the impedance can be written in the form of a complex number. The real term is the resistance, while the imaginary is the reactance.

The reactance is usually divided into two parts, namely, inductance and capacitance; we must now enquire into the exact meaning of these two terms.

Inductance.

The idea of inductance arises directly from Faraday's law. If a certain field of force is produced by a conduction current flowing in a circuit and an E.M.F. is induced in another by this field, the value of the E.M.F. is equal to a constant multiplied by the rate of change of that current. This constant is called coefficient of induction and depends on the shape and position of the two circuits carrying the conduction current and induced E.M.F. It is self-induction when the same circuit carries both the current and the induced E.M.F., and mutual induction when the two circuits are separate.

Since we have defined induced E.M.F. for portions of a circuit, it is possible to define coefficients of self and mutual induction for incomplete circuits. Let us suppose that AB and CD are two incomplete circuits and that conduction currents varying with time can be made to flow in them. It is not intended to consider whether this is practically possible or not. Then, if we keep the current in CD constant and vary that in AB, the coefficient of self-induction L_{AB} in AB will be given by the ratio of the E.M.F., E_{AB}, induced in AB and the rate of change of the current.

That is

$$L_{AB} = -\frac{E_{AB}}{di_{AB}/dt} \quad \cdots \quad \cdots \quad (12)$$

If the E.M.F. induced in CD is E_{CD}, the coefficient of mutual inductance M will be given by

$$M = -\frac{E_{CD}}{di_{CD}/dt} \quad \cdots \quad \cdots \quad (13)$$

It may be noted that the definition for the induced E.M.F.s are the same as stated above. E_{AB} is the sum of the terms $\partial A/\partial t$ along AB. For the mutual inductance, however, when the two parts *AB* and *CD* are considered as separate, E_{OD} is the sum of the $\partial A/\partial t$ and $\partial \phi/\partial x$ terms. For the self-induction, then, the value depends on the conduction current only, while for the mutual induction we must also take into account the effect of the distribution of charge. It must be noted, however, that the sum of the $\partial \phi/\partial x$ terms taken round a complete circuit is zero. When dealing with complete circuits, therefore, no difficulty arises, since the induced E.M.F. can be taken to be due to the magnetic field alone and the effect of the distributed charges can be neglected without infringing the mathematical rigorousness of the analysis.

Capacitance.

The reader may have noted that the word current has often been qualified by the adjective conduction. Maxwell was responsible for dividing currents into two categories, which he called conduction and displacement currents. The former, conduction current, refers to the flow of charge. The latter, displacement current, is only another way of expressing the rate of change of stress in a dielectric. The *total current* (*i.e.*, the sum of the conduction and displacement currents) entering any closed surface must always be equal to that leaving it. If the conduction current entering a closed surface is greater than that leaving it, the balance must be made up by the dielectric current. In such a case, however, a charge is being accumulated within the closed surface. Such a phenomenon is called a "Capacity Effect."

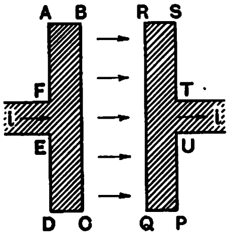


Fig. 4.

As an example, let us consider the most simple and common case of a condenser. *ABCD*, *PQRS* are the two plates of the condenser (Fig. 4); all the shaded portions are of metal. Consider the plate *ABCD*. A conduction current i enters this surface at *EF*, but none leaves it. There must accumulate within the surface *ABCD* a charge and, from definition, displacement currents of total value i must flow away from the surface of the plate. If the other plate *PQRS* completely surrounds *ABCD*, as in a totally screened condenser, the whole of the displacement current must fall on the plate *PQRS* and there produce an equal and opposite charge to that produced in the plate *ABCD*. Now this charge in the plate *PQRS* cannot be produced without the aid of conduction current. It is therefore necessary for a conduction current i to flow out of the plate *PQRS*. Thus, conduction current enters one plate and produces a charge. There is therefore a capacity effect. At the same time, conduction current leaves the other plate and produces an equal and opposite charge. As before there is a capacity effect. Since the displacement current flows through the dielectric from one plate to the other, the capacity effect is said to be between the two plates.

Very often the conditions are not as simple as this. For instance, a conduction current in a wire at high potential passing near an earthed conductor will vary in magnitude from point to point because displacement currents flow from the wire to the earthed conductor and charges are accumulating along the wire. We then say that there are capacity effects between the various points of the wire and the earthed conductor. There are three criterions of a capacity effect in alternating current circuits. They are merely different manifestations of the same thing. They are:

(*a*) A difference between the conduction current entering and leaving a given closed surface.

(b) The existence of a charge within a closed surface.

(*c*) The existence of unclosed loops of displacement current.

In the dielectric we have, therefore, lines of flow of displacement current. These lines of flow terminate on bodies capable of carrying a conduction current, and at these junction points a charge is accumulated. If i_1 is the difference between the outgoing and incoming conduction currents of a closed surface, and i_2 the same difference for the displacement currents, the charge q accumulated in the closed surface is given by

$$-\int i_1 dt = \int i_2 dt = q \qquad .. \quad (14)$$

A tube of flow or displacement current starts from a negative charge q and ends on an equal positive charge. If the potential difference between the ends of the tube of flow is V, the capacity C connected with that particular tube is defined as

$$C = q/V \quad \ldots \quad \ldots \quad (15)$$

Now the flow of the displacement current depends on the distribution of electric intensity in the dielectric (*i.e.*, on the lines of force of the sum of the $\partial A/\partial t$ and the $\partial \phi/\partial x$ terms)*. We therefore see that there is a difference between the values of the capacity between two bodies in electrostatics and in an alternating current circuit. Since the dielectric intensity depends on the frequency, a given system of conductors will produce a configuration of displacement currents in the surrounding dielectric which will vary with the frequency. From equation (14) we see that this is equivalent to saying that there will be a different distribution of charges for each frequency. Not only will the charges be different but, since potential difference is obtainable directly from the charges only, this will also vary with frequency.

We may now complete the qualitative analyses of the two circles of wire A and B of Figs. 2 and 3. We saw in the second case, when the circles were eccentric, that charges must accumulate in the circle A to produce suitable values for the $\partial \phi/\partial x$ terms which will balance the E.M.F. induced. Since a charge accumulates there must be a capacity effect. This is what we expect. Since there are potential differences between the various points of the wire A, we would expect displacement currents to flow from one part of the wire to another, thus allowing a charge to accumulate on the wire. When, the two circles A and B are symmetrically above each other, as in Fig. 2, there is no potential difference and, therefore no displacement current between one part of the wire and any other. There can, therefore, be no capacity effect in this case and no charges accumulate, a result which agrees with the ideas outlined above.

Distributed Capacity and Inductance.

In many problems it is difficult to calculate the tubes of flow of the displacement currents and attach to each a correct capacity. It is often convenient to represent those capacities as going from one point to another convenient point irrespectively of the exact beginning and end of the tubes of displacement current. It is also often convenient to represent a wire as an infinite number of inductances all in series with their common points joined by condensers to suitable points as in Fig. 5. The criterion of the existence of those capacities is a change of conduction current along the wire, which change shows that there is a displacement current in the dielectric. Such arbitrary representation may appear very drastic, but, when intelligently carried out, produce enormous simplifications in the mathematics and give results to a remarkable degree of accuracy, for reasons that are given below.

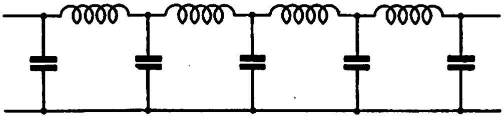


Fig. 5

The most common problem in which such a representation is used is that of the transmission line. In this problem the terms capacity per unit length and inductance per unit length are commonly used. It is usual to assume that this does not represent rigorously the lines of flow of the displacement currents, but that does not necessarily imply that the terms capacity per unit length and inductance per unit length are only approximate or, alternatively, are meaningless, as Professor Howe might lead one to infer. If they are approximate they must approximate to something rigorously correct, and we must endeavour to find this.

If we know the distribution of current and potential difference between the points to which the condensers are connected, there is no great difficulty in rigorously defining the terms capacity and inductance per unit length.

If i is the current at any point and V the potential difference between the terminals of the condenser at that point, the capacity

---

* In fact, calling the electric intensity E, the displacement current is

$$\frac{K}{4\pi}\frac{\partial E}{\partial t}$$

per unit length, C, is the ratio of the change in the value of the charge in a unit length to the potential of that unit length or mathematically

$$C = -\frac{1}{V}\int\frac{di}{dx}dt \qquad .. \ (16)^*$$

Similarly the self-inductance per unit length, L, is the ratio of the change in the value of V in a unit length and the rate of change of the current in that unit of length. Mathematically this can be written

$$L = -\frac{dV}{dx}\Big/\frac{di}{dt} \qquad .. \ (17)^*$$

It will be seen that these definitions include the reaction of distant portions of the system. That is, in C we find the capacities to all parts, and in L the E.M.F. due to the mutual inductances of all parts, on the unit length considered.

The utility of these definitions may not be apparent since they depend on knowing the result. They are useful, however, in many cases for obtaining approximate results; in the theory of antennæ, for example. The values of the self-inductance and capacity per unit length at any point will depend mainly on the distribution of the charge and the current in the neighbourhood of the point considered. If this distribution is approximately the same as that which would obtain in electrostatics (or more correctly at infinitely low frequency) it will be a fair approximation to assume the distribution of capacity and inductance per unit length is the same at all frequencies.

It should be realised that this approximation is essentially dependent on the use of thin wires and plates. That is the distribution of charge and current in the neighbourhood of any point should be approximately the same at all frequencies considered over a distance which is large compared to the thickness of the wire or plate. That is, the wavelength should be very large compared with this thickness, a condition which almost invariably exists.

Summary.

The following definitions have been obtained.

(*a*) *Scalar potential* (ϕ) is the same as the potential found in electrostatics from the distribution of charges (q) alone

$$\phi = \Sigma\left(\frac{q}{r}\right)^* \qquad .. \qquad .. \ (18)$$

(*b*) *Vector potential* (A) is similar to the scalar potential but current is substituted for charge. It has both magnitude and direction, the direction being parallel to the current

$$A_x = \Sigma\left(\frac{i_x}{r}\right)^* \qquad .. \ (19)$$

where c is the velocity of light and the quantities are measured in electrostatic units

(*c*) *Electric intensity* (E) is given by

$$E_x = -\mu\frac{\partial A_x}{\partial t} - \frac{\partial\phi}{\partial x} \qquad .. \ (20)$$

When applied to a conductor of resistance R, per unit length, we have

$$\mu\frac{\partial Ax}{\partial t} + \frac{\partial\phi}{\partial x} + Ri_x = 0 \qquad .. \ (21$$

(*d*) *Potential difference* (V) is the potential difference due to the distribution of charges on the section of the circuit under consideration only, calculated as though the problem were an electrostatic one.

(*e*) *E.M.F.*, in the case of self-inductance, is the value of the sum of the $\partial A/\partial t$ terms integrated along the circuit. In the case of mutual inductance it is the sum of the electric intensity integrated along the circuit.

(*f*) *Impedance* (Z) is the ratio of the potential difference (V) between the terminals of the apparatus considered and the current (i) at some definite point either inside or outside the apparatus, when no E.M.F. is induced from outside sources within the apparatus.

$$z = V/i \qquad .. \qquad .. \ (22)$$

(*g*) *Coefficient of induction* is the ratio of the E.M.F. induced and the rate of change of the conduction current. In the case of self-inductance the conduction current in the wire AB is inducing the E.M.F. on the same wire

---

* It may be noted that the velocity of electrical disturbance along wires is not accurately equal to the velocity v of light in vacuo, so that the equation $v = 1/\sqrt{LC}$ given by Professor Howe is not rigorously correct.

* Rigorously, the value of the charge q or the current i_x, is that which existed at a time r/c previous to the instant considered, because the action is not instantaneous but travels with the velocity of light.

$$L_{AB} = -\frac{E_{AB}}{di_{AB}/dt} \quad .. \quad (23)$$

In the case of mutual induction the conduction current in the wire CD induced the E.M.F. in the wire AB

$$M = -\frac{E_{CD}}{di_{CD}/dt} \quad .. \quad (24)$$

(*h*) *Conduction Current* (i_1) is a measure of the flow of charges q with a velocity v.

$$i_1 = q \cdot v \quad .. \quad .. \quad (25)$$

(*i*) *Displacement Current* (i_2) is a measure of the rate of change of dielectric stress.

$$i_2 = \frac{K}{4\pi} \cdot \frac{dE}{dt} \quad .. \quad .. \quad (25)$$

where E is the electric intensity and K the dielectric constant.

(*j*) *Capacity* (C) corresponding to a tube of displacement current is the ratio of the charge at the end of the tube to the potential difference across it.

$$C = q/V \quad .. \quad .. \quad (27)$$

(*k*) *Self-Inductance per Unit Length of a Wire* (L) is the ratio of the gradient of the potential difference at a given point of a wire to the rate of change of the current at that point;

$$L = -\frac{dv}{dx}\bigg/\frac{di}{dt} \quad .. \quad .. \quad (28)$$

(*l*) *Capacity per Unit Length of a Wire* (C) is the ratio of the charge per unit length at a point of the wire to the potential difference, V, across the (assumed) condenser.

$$C = -\frac{1}{V}\int\frac{di}{dx}dt \quad .. \quad (29)$$

It may be mentioned that definitions (*k*) and (*l*) are of no practical utility unless the thickness of the wire is small compared with its length, with the distance from neighbouring conductors, and with the wavelength.

Book Reviews.

LETTERS PATENT FOR INVENTION.*

At one time or other most workers in the field of wireless science have dallied with the notion of taking out Letters Patent, to protect either some sudden and brilliant inspiration or else a well-thought-out improvement on existing circuits. Yet it is curious how few of those who piously expect the Patent system to protect them from unauthorised piracy really understand the basic principles upon which this system works.

Its origin is buried in the midst of antiquity, being founded not upon Statute Law, but upon the Royal Prerogative. Its aim is to foster and encourage industry—by giving the inventor a temporary monopoly, so that the community at large may reap a larger benefit when the monopoly grant has expired.

Mr. Griffiths' book is not intended to guide the amateur inventor through the formalities and intricacies of Patent Office procedure, so much as to explain the fundamental ideas underlying the legal and common-sense structure of the system of monopoly grants *per se*.

A short historical survey is followed by a brief account of the essential nature of a patentable invention. It must be a " manner of manufacture " and not a mere discovery, nor yet a process of nature operating without the aid of machinery or apparatus.

The invention must have novelty and utility, though this last asset is more a matter for the Courts than for any official examination made prior to the grant. Yet if it be absent, the Courts will declare the patent, even if granted, void " for want of consideration."

The rights of the patentee are considered as well as the penalties for infringement and the procedure involved in an action for infringement. The manner in which patent rights devolve upon, or may be assigned to other parties, is touched upon, together with the question of licences and the relationship created between licensor and licensee.

A special chapter is devoted to the " Abuse of Monopoly Rights," a matter which is of outstanding interest in wireless circles at the present juncture.

EXPERIMENTAL RADIO. By R. R. Ramsay, Ph.D.

Third edition. Published by the Ramsay Publishing Co., Bloomington, Indiana, U.S.A. Price $2.75, post free.

A review of the second edition of Prof. Ramsay's book appeared in our issue for September, 1927 when we stated that the only adverse criticism to be made was that some of the diagrams in that mimeographed edition were badly drawn. The book has now been reprinted and the diagrams greatly improved, so that this adverse criticism no longer applies to the new edition.

---

* " Patent Law and Practice. By A. W. Griffiths, B.Sc., Barrister-at-Law. Published by Stevens and Sons, Chancery Lane. 7s. 6d. net, pp. xvii and 174.

A Portable Oscillograph Equipment for the Observation of Transient Electrical Phenomena.

By *Philip R. Coursey, B.Sc., M.I.E.E.*

THE basis of this apparatus is the latest pattern of three-element oscillograph constructed by the Cambridge Instrument Co., Ltd. This instrument consists of a metallic case holding the optical portion of the apparatus and carrying also places for three oscillograph vibrators, which may be either of the electromagnetic or of the electrostatic type, as desired, the two types being interchangeable.

This equipment is designed by the makers for photographic recording of the oscillograph records by means of a drum camera which can be attached to the end of the oscillograph case. The camera drum is normally driven round by a small electric motor, and the shutter of the camera is arranged for opening automatically by a cam mechanism, so as to permit of exposure of the film during a quarter, a half, or a complete revolution of the drum. Visual indication of the oscillograph record is obtained also by a rotating mirror when the camera film is not being exposed.*

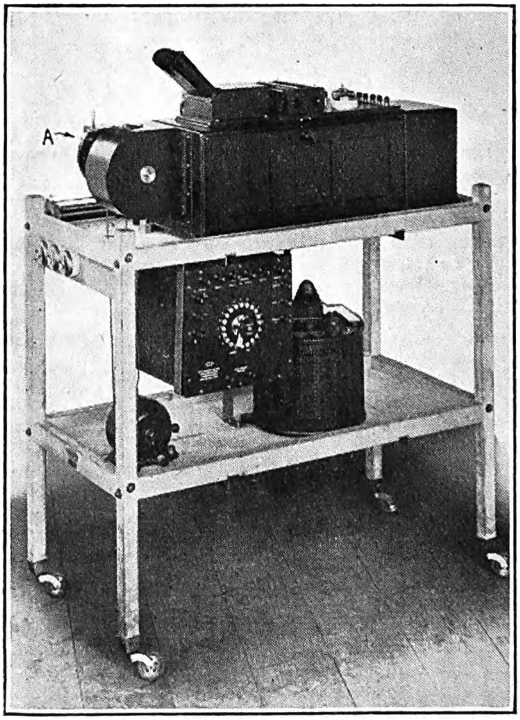


Fig. 1.—*Arrangement of oscillograph equipment on wheeled trolley. The special shutter release is marked A. Adjustable shunt for current measurements and adjustable resistance for voltage measurements are mounted beneath main instrument.*

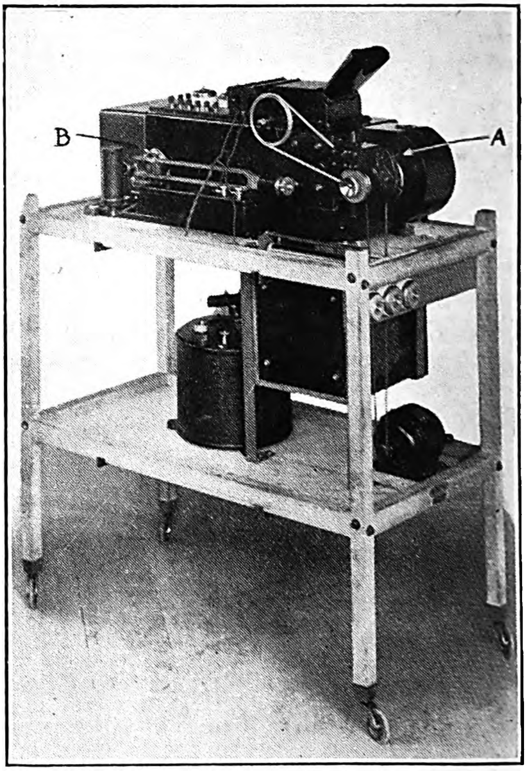


Fig. 2.—*Tuning fork timing mechanism for oscillograph. The shutter for timing beam is marked B and A is the camera shutter release.*

The equipment as thus arranged is eminently suited for recording stationary or periodically repeated electrical current or voltage waveforms or phenomena, but is quite unsuited for obtaining a record of a transient phenomenon unless the time of occurrence of the transient is definitely known and controllable. For instance, the waveform of the current and/or voltage in a circuit fed from an A.C. source of constant frequency can easily be recorded, as also can changes in the waveform when these are produced by switching, or similar means which can be linked mechanically or electrically with the control handle of the camera shutter so as to ensure that the exposure of the film is made at the correct instant. A change in the conditions of an electrical circuit produced by causes beyond the control of the operator cannot, however, be recorded by this arrangement.

---

* *Journal of Scientific Instruments*, 5, pp. 103-107, March, 1928.

For the purpose of certain experimental investigations in the laboratory of the Dubilier Condenser Co., Ltd., the observation and photographic recording of transient electrical phenomena was required. For this purpose certain modifications of the standard instrument have been carried out in order to overcome the above-mentioned difficulties.

First, as the instrument was required to be moderately portable without the necessity for setting up the apparatus and its accessories on each occasion, it was mounted on a small trolley fitted with small rubber-tyred wheels, Fig. 1. The oscillograph itself was fitted to the upper tray of the trolley, the weight being taken by two small strips of angle-iron fixed below the tray and fastened to the main framework. The small motor used for driving the camera drum and the rotating mirror was mounted on a lower shelf so that the driving belt passed straight up to the camera wheel above. The regulating resistance, connected in series with the motor for controlling its speed, was mounted on the top tray alongside the oscillograph case so as to be easily accessible when observing through the window provided. Three switches were also fitted, one for the motor, and two others for the lamp circuits, one being for the main lamp providing the light for the vibrators, and the

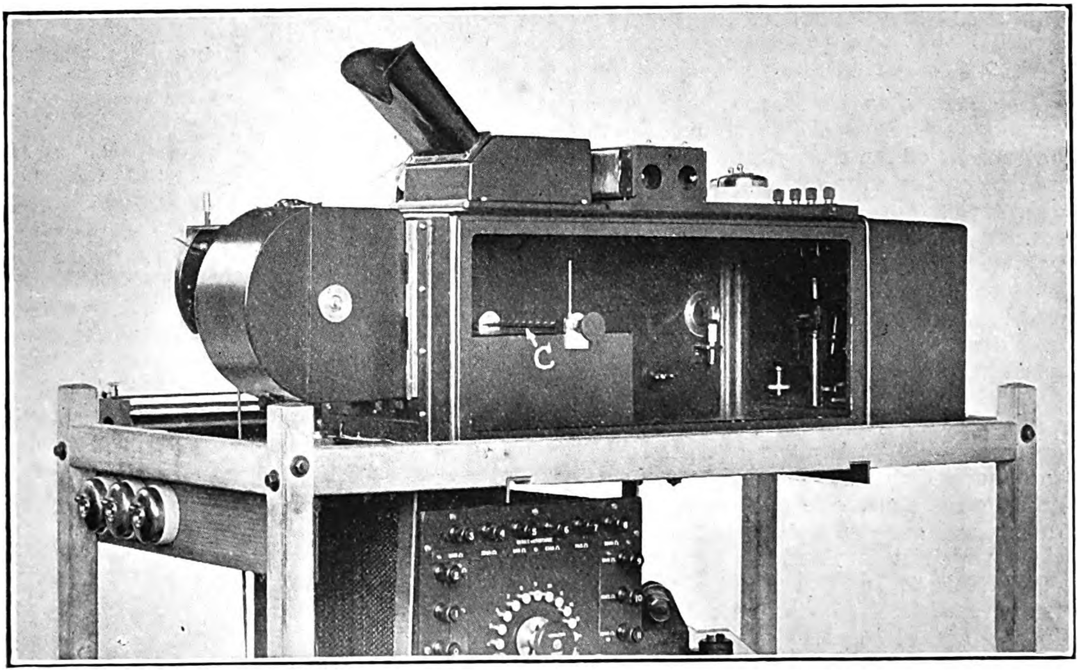


Fig. 3.—*Interior view of oscillograph case, showing adjustable position "shadow rod" C.*

other for an auxiliary lamp used to provide a time scale marking on the film in conjunction with a tuning fork.

The shunt-box supplied by the Cambridge Instrument Co. to enable current waveform measurements to be made up to currents of 100 amperes was also mounted on the lower shelf of the trolley, and connected up to one of the vibrator positions to enable observations of current waveforms to be taken immediately when required. For voltage waveforms a combined series resistance and vibrator shunt was constructed and mounted immediately beneath the oscillograph so as to be readily accessible when taking visual observations.

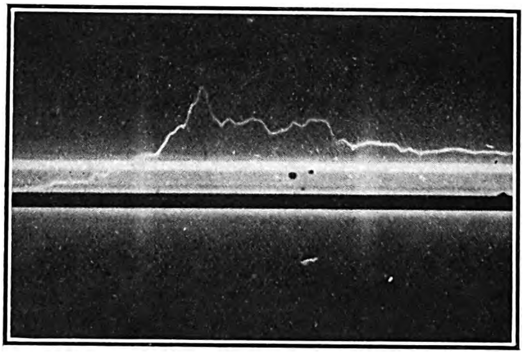


Fig. 4.—*Oscillogram of surge in D.C. circuit. (The black line is the "zero" shadow line; the straight white line is a calibration line for the voltage scale and indicates the normal circuit voltage.)*

To enable transients to be photographed when the time of their occurrence is only approximately known, it is necessary for the camera drum to be rotating continuously, and for the shutter to be opened for a predetermined time so as to include the transient which it is intended to record. To enable this to be carried out a small lever has been fitted to the instrument at *A*, Figs. 1 and 2, so as to engage the existing camera shutter mechanism and so to open and release the shutter independently of the normal cam-mechanism, to which reference has already been made. The film can thus be exposed to the trace of the vibrators for a predetermined length of time—covering several revolutions of the camera drum.

The mechanism for providing a time scale to the record may be seen in Fig. 2. It consists of an electrically driven tuning fork, having a frequency of 50 per second, which opens and closes a small slit shutter so as to allow a narrow beam of light to pass into the oscillograph case 50 times per second. This beam is concentrated into a narrow line by means of a cylindrical lens, so that a series of lines is obtained across the film, spaced 1/50 second apart. With the normal use of the camera using the cam-mechanism to limit the exposure time, the light from the fork can be allowed to pass continuously, but with continuous rotation of the camera drum, overlapping and consequent confusion of the time marking would occur. An ordinary type of camera shutter has therefore been fitted to the hole in the oscillograph case through which the light from the fork is passed. This may be seen at *B*, Fig. 2. This shutter enables the timing markings to be made on the film for a small fraction of a second only, so that they occur on the film during a part only of one revolution. The duration of the admission of light in this manner is adjustable by the shutter as in the case of an ordinary camera. A period of approximately 1/5 second has been found convenient. Since for the normal short periods of exposure the speed of

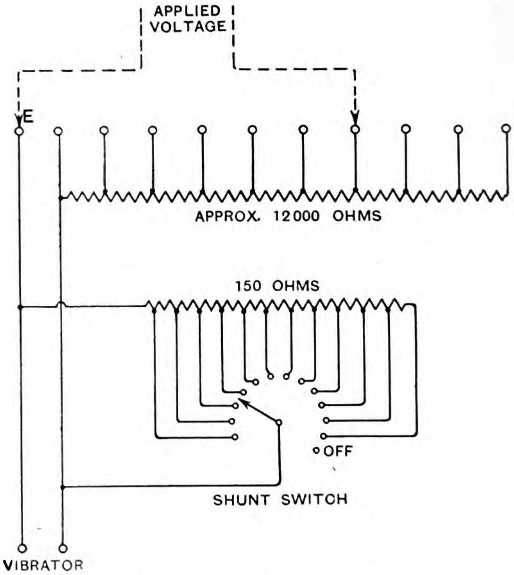


Fig. 5.—*Circuit diagram of combined series resistance and shunt box for oscillograph vibrator.*

rotation of the camera drum may be regarded as constant, the time scale for the whole record is thus obtained, even although the markings extend for a portion only of the length of the film.

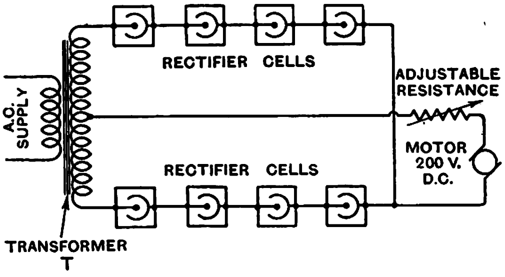


Fig. 6.—*Arrangement of electrolytic rectifier to operate D.C. camera motor from A.C. supply circuits.* (*The transformer T steps up the supply voltage from* 220 *to* 500 + 500 *volts.*)

A continuous rotation of the film in this manner with a stationary trace from an oscillograph vibrator tends to produce fogging of the film on account of unavoidable scattering of some light beyond the actual width of the " spot " on the film. A small rod has therefore been mounted in the oscillograph case in a vertical position so as to intercept the normal undeflected ray from one of the vibrators. The position of this shadow rod can be adjusted by means of a transverse screw carried by small supporting brackets, as may be seen more in detail at *C* in Fig. 3.

In Fig. 4 is reproduced a record taken with this equipment, in which the break in the trace caused by the shadow rod can be seen. This oscillogram shows a surge caused by the sudden opening of a short circuit on a line with D.C. voltage applied to it, the record indicating a pressure rise considerably in excess of the normal applied voltage.

The resistance box shown in the photographs for taking voltage curves with the electromagnetic vibrator is arranged as in the diagram Fig. 5, so that it acts both as a shunt for the vibrator and as a series resistance. The main resistance has a total value of approximately 12,000 ohms, and is suitable for a maximum voltage applied between its ends of 1,000 to 1,200 volts (R.M.S.). When the shunt switch is in the " off " position, the vibrator is joined directly in series with the high resistance, but as the switch is rotated a variable shunt resistance is connected across the vibrator. This permits easy control of the amplitude of the deflection of the vibrator without changing the high voltage connections. At the same time, also, it permits the main circuits to be closed with the vibrator short-circuited and therefore reasonably safe from damage, after which the shunt switch can be turned gradually until a convenient deflection is obtained.

The motor for driving the camera drum and rotating mirror of the oscillograph is normally operated from 200 volts D.C., with a series resistance to control the speed. In certain cases, however, when a suitable D.C. supply is not available, it has been found practicable to operate this motor from an A.C. supply through the medium of a small electrolytic rectifier—Fig. 6. The transformer *T* steps up the supply voltage (200/240 V, 50 ~) to approximately 1,000 volts, which is used to supply the two banks of rectifier cells, connected to give rectification of both half-waves of the supply.

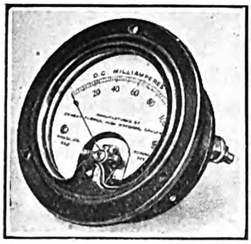
With eight small tantalum wire rectifier cells for each half of the rectifier, a supply of 120–150 mA. at 200 volts D.C. is obtained for the motor and this has proved quite adequate for most requirements. The rectifier cells used in this arrangement are each only about 1 in. diameter × 3 in. high, and are of a type often used in rectifier equipment for " battery eliminators " furnishing H.T. supply to radio receivers.

This rectifier equipment is quite a compact one and can be fitted to the oscillograph trolley when required for use when an A.C. supply only is available. The whole set-up has proved a very convenient and portable arrangement that lends itself to a variety of experimental investigations.

Scientific Instruments at Olympia.

A Review of some Apparatus of Laboratory Interest exhibited at the Recent Radio Show.

THERE can be no manner of doubt whatever that the recent Radio Exhibition at Olympia, from the point of view of those interested in the reception of broadcasting, contained a very large number indeed of extraordinarily interesting exhibits, but we must regretfully place on record our opinion that, for those primarily interested in laboratory work with high-frequency currents, and who therefore went to Olympia with the hope of seeing the latest developments in measuring instruments suited to their purposes, the Show was, on the whole very disappointing. Not only were several of the most famous makers of scientific instruments completely unrepresented, but even those who had stands occupied them in several cases purely in their capacity as makers of sets for broadcast reception. In the case of two firms, for example, who were making scientific instruments long before broadcasting was thought of, their exhibit was so purely directed towards broadcasting that they were not able to produce even a catalogue of their scientific instruments, though a promise was made, and promptly fulfilled, to send a copy of it by post from their Head Offices. From the point of view of those interested in wireless research work, the most notable absentees were the Cambridge Instrument Company, who hold manufacturing rights for the Moullin voltmeter. Their absence is the more to be regretted as they have produced during the last year three new models of this instrument, which is perhaps more frequently used in high-frequency work than any other.

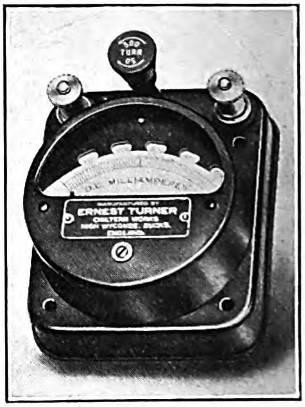


The Turner Model 505 milliammeter.

In considering the measuring instruments of various types that were to be seen, it will be convenient, both for comparison and reference, to group them by types rather than by makers, and to deal first with the biggest and most fundamental class, consisting of meters for direct current.

Direct-current Meters.

Meters for direct-current measurements were to be seen in a very wide range of types, from the small and remarkably inexpensive instruments intended to be left permanently in the plate circuit of the output valve of a receiver, but claiming to do little more than indicate overloading by showing up variations in plate current, to really good instruments guaranteed to give readings accurate within very small limits.

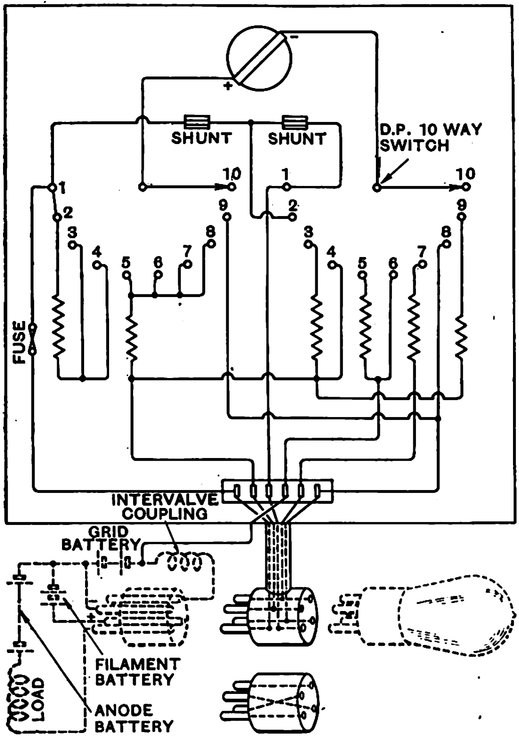


The Turner Model 707 moving dial double range milliammeter.

Mr. Ernest Turner, of High Wycombe, Bucks, was showing, on the stand of Messrs. Bakelite, Ltd., who make the cases for his instruments, a complete range of D.C. meters. These are available in several sizes at varying prices; the smallest series, known as Model A1, have a body diameter of 2½in. and sell at prices round about £2 10s. As milliammeters they have ranges from 0 to 1.5 mA. up to 0 to 750 mA., and the series is continued as ammeters reading up to 20 amps. In all these the voltage-drop across the instrument at full-scale reading is from 75 to 100 millivolts, indicating a resistance varying from some 50 ohms in the most sensitive of the series down to 0.1 ohm for the 1 amp. model. There is also available a galvanometer of the pointer type, with a centre zero, giving a deflection of one division per 20 microamps.

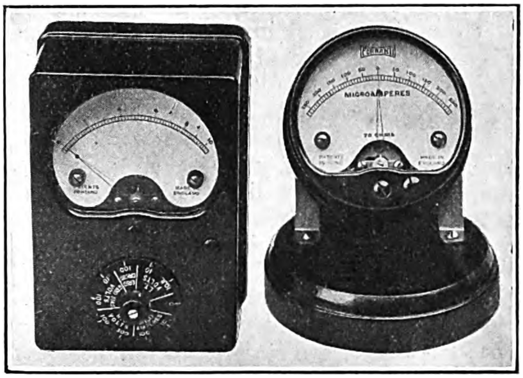
These instruments are also made up as voltmeters, in all ranges from 1 volt to 50 volts, and having in all cases a resistance of 133 ohms per volt, though higher resistances can be obtained to order. The resistance mentioned corresponds to a current of 7·5 mA. at full-scale reading.

The same maker produces larger instruments covering much the same ranges at rather higher prices; in these the same standards of resistance for both current and voltage meters are retained. In addition, a series of double-range instruments is produced, these having the interesting and novel feature that by operating the switch that alters the range the figures on the dial are also altered, so that there can be no danger of misreading, or accidentally overloading the instrument, by any confusion between the two ranges.



Circuit diagram of the Ferranti valve-tester.

All instruments made by Mr. Turner are guaranteed accurate within 1 per cent. of full scale reading for all positions of the pointer above half-scale reading; below this the accuracy is within 0.5 per cent. This standard is that prescribed in the British Engineering Standards Association Specification No. 89 for first-grade instruments, and will be referred to hereafter in this review as "B.S.1 Standard." It was interesting to learn that although these instruments have not been available to the public until comparatively recently, they have been produced in considerable numbers for large users, such as various Government departments and the B.B.C., for a considerable period.



The Ferranti valve-tester and pointer galvanometer.

The range of small instruments produced by Messrs. Ferranti, Ltd., will probably be known to most readers. It comprises a series of milliammeters with full-scale readings varying from 1 mA. up to 150 mA., which is extended by ammeters reading to from 0.75 to 20 amps. Throughout the series the voltage-drop across the shunt amounts to 75 mV., indicating that a satisfactorily low resistance has been attained. The price of these instruments is £1 10s. for all but the lowest range, and the standard of accuracy claimed is B.S.1. An unusual feature is the inclusion of a fuse in each instrument, whereby immunity from burnt-out coils and bent pointers may be expected; spare fuses can be obtained for a few pence. The aluminium pointers of these instruments appear to be very light, though the girder construction used evidently gives them considerable mechanical strength. A centre-zero galvanometer, reading 250 to 0 to 250 microamps., is also available.

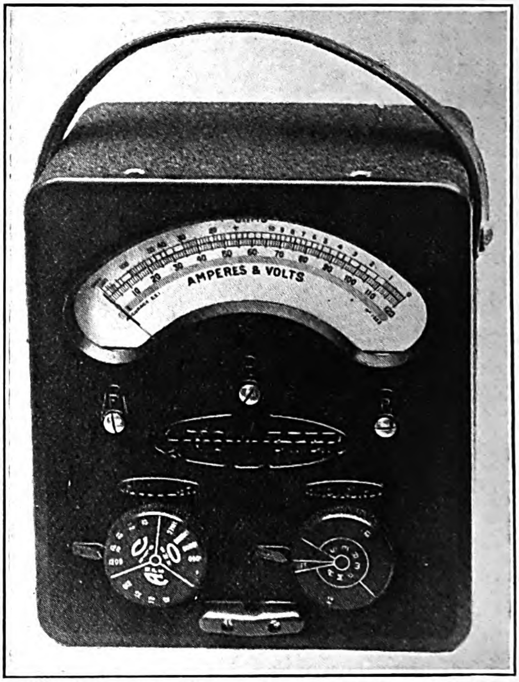
A corresponding range of voltmeters is made, the standard resistance of these being 200 ohms per volt, though on the higher ranges a resistance of 1,000 ohms per volt may also be obtained at a higher price.

Multi-range instruments are also available, these being primarily designed for permanent inclusion in a wireless receiving set, so that adequate control of battery voltages and plate currents may be obtained. They can, however, readily be adapted for laboratory use.

Those whose work involves the "servicing" of receiving sets will be interested in the "Valve Tester," made by Messrs. Ferranti; with this instrument it is possible to make all the essential measurements of voltage and current for any valve in a receiver under the actual conditions obtaining in the set itself. To do this the valve is removed from its socket, a plug attached to a flexible lead being put in its place. The valve is then inserted in a valve-holder mounted on the top of the plug. This returns the valve to its appropriate circuits, while the connections within the plug are such that it is possible to measure, by turning a switch on the multi-range "Valve Tester," the anode voltage and current, the filament voltage, and the grid-bias voltage. For all these measurements, except that of filament voltage, two alternative ranges are provided, so that the Tester can be used with practically any type of valve from a D.E.3 to an L.S.5a.

Another example of a "service" Testing Set was shown by Messrs. R. I. and Varley. This is a very useful instrument, designed principally for the requirements of those whose business it is to "service" wireless receivers in the home and trace faults, and for this reason it is built as compactly as possible, weighing 13¼ lb. in all, the overall dimensions being 12 in.×11⅝ in.×7½ in.

The R.I. Varley testing set.

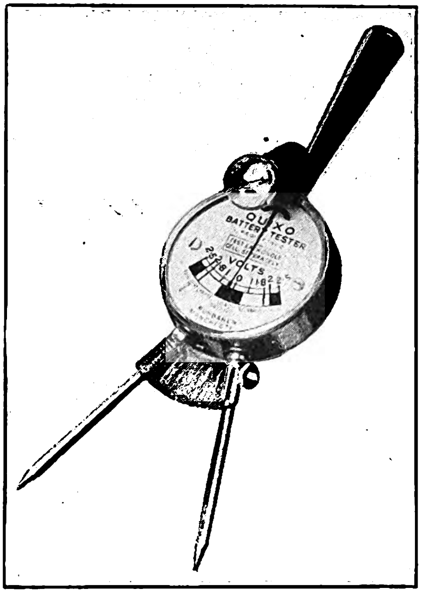


The "Avometer," a multi-range instrument for measuring voltage, current, and resistance.

The instrument is mounted in a mahogany case, provided with a carrying strap, and includes a 3-range Weston voltmeter—10, 50, and 250 volts—having a resistance of approximately 1,000 ohms per volt, and a 3-range Weston milliammeter—15, 150 milliamps., and 3 amperes. A Neon lamp with key is fitted for the purpose of checking continuity and insulation resistance of circuits. Voltage and current measurements can be made and valves can be tested for all ordinary faults. The instrument sells at £16.

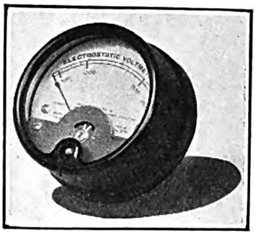
Another ingenious multi-range instrument, intended for general laboratory work, is marketed by the Automatic Coil Winder & Electrical Equipment Co., under the name of the "Avometer." This is intended to cover in one instrument all the most generally used ranges, and will measure currents from 12 mA. to 12 amps., volts from 0.12 to 1,200, and, by the use of a small dry battery incorporated in the instrument, it is also available for resistance measurements from 1,000 ohms up to 1 megohm. The figures given here are in each case full-scale reading. The resistance of this instrument arranged as a voltmeter is 167 ohms per volt, and the accuracy claimed on all ranges is B.S.1 Standard. The price of the complete instrument is £8 8s.

Cheaper meters, suitable for general testing purposes rather than for real laboratory work, were offered by Messrs. A. H. Hunt, Ltd. In addition to the usual moving-iron instruments, moving-coil meters in all ranges from 5 mA. to 50 amps, and from 2.5 to 250 volts are made, together with several varieties of multi-scale instruments. The price of these is from about £1 upwards, and the accuracy claimed is from 1 to 2 per cent. Voltmeters have a resistance of some 120 ohms per volt, while the voltage-drop across the milliammeters is round about 225 millivolts; these figures do not remain quite constant throughout the range.



The "Quixo" cell-tester of Messrs. Runbaken, for testing the state of charge of an accumulator cell.

Messrs. Siemens also produce meters of the general-purpose type, these being specifically designed for use with the amateur's wireless receiver. Two meters were exhibited, one a voltmeter with ranges to 7.5 and 150 volts, with a resistance of 300 ohms per volt, while the other measures current as well as voltage, the full-scale readings being 3, 15 and 150 volts, or 7.5, 75 and 750 mA. This latter meter is ingeniously arranged with only two terminals, the necessary range-changes being made by moving a plug from one socket to another. The accuracy claimed for both meters is 4 per cent.

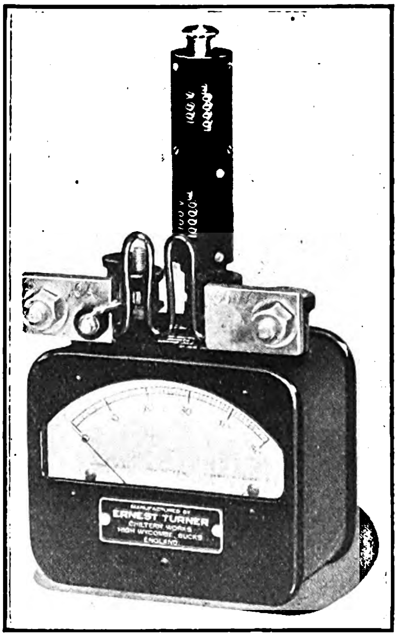


Turner electrostatic voltmeter.

Messrs. Runbaken were showing, not for the first time, an ingenious and simple cell-tester which permits one to find out, by a single rapid test, whether an accumulator is or is not discharged. A voltmeter test, as is well known, is quite unreliable, as any cell that is in reasonable condition will show full voltage after standing for a few moments without load. Similarly a hydrometer test is only of value if it is known that the acid has exactly its correct specific gravity when the cell is fully charged, which is seldom the case in a battery that has had some months of service. This "Quixo" cell-tester consists of a voltmeter shunted by a piece of stout resistance wire which, with two volts across it, draws a current in the neighbourhood of 12 amperes, so that the voltage of the cell is tested while under a heavy load. Under these conditions the test will show with certainty whether the cell requires a charge. A second model of this tester is made in which the load taken can be adjusted, while much more heavily built models are available for testing motor car batteries and other large installations, these drawing currents in the neighbourhood of 100 amps. Though the currents taken during the test are high, the duration of the test is so small that no damage to the batteries need be feared, though some care would perhaps be needed in using the cell-tester with slow-discharge cells made up with thick plates.

Meters for Alternating or High-frequency Currents.

The only representative of the hot-wire type of meter that was seen at the Exhibition was that made by Mr. Turner, who makes a range of seven meters at prices from £1 10s. Full-scale reading on the various models is from 0.25 to 3.0 amps. Owing to the liability of these instruments to errors, which is inherent in the principle upon which they operate, the newer type, consisting of a sensitive D.C. instrument reading the current yielded by a thermo-couple which is heated by the passage of the current to be measured through a fine resistance wire, is rapidly supplanting the simpler type. These also are made by Mr. Turner, and are marketed under the title of Thermo-ammeters at prices ranging from £4 5s. upwards. There is little in appearance to distinguish them from the other products of the same maker, except that the scale is not linear. It is to be noted that the heater is welded direct to the couple, and that one of the terminals is grounded to the metal case; this arrangement may or may not be approved, according to the purpose for which the instrument is to be used. The ranges available are thirteen in number, the lowest requiring 500 mA. for full-scale reading, and having a heater-resistance of 2.8 ohms, while the highest range reads up to 12 amps. These instruments can be used for currents of all frequencies, and are also available for use, if this should be required, for direct current, the same calibration holding good. The accuracy of these meters is guaranteed within 1 per cent., and they will safely withstand a temporary overload of 50 per cent.



Turner portable D.C. volt-ammeter. A self-contained multi-range instrument, fitted for outside multipliers for additional ranges.

Messrs. Ferranti make a meter of similar type in a number of ranges from 25 mA. up to 5 amps. The direct-current meter used for these is their standard small meter with a specially wound coil. In these instruments the heater is insulated from the thermo-couple, which is a great convenience when it is impossible to arrange to insert the meter at an earthed point in the circuit. Unlike the hot-wire instruments, the temperature error in these particular samples of the thermo-couple type is only about 0.1 per cent. per degree Centigrade, while the heater consumes only about 20 milliwatts, corresponding to a resistance in the 25 mA. instrument of about 32 ohms, with a voltage-drop of about 0.8 volt. High-frequency voltmeters, which are, of course, equally suitable for use on ordinary alternating or direct current, are also made on this principle; they have a resistance of 40 ohms per volt.

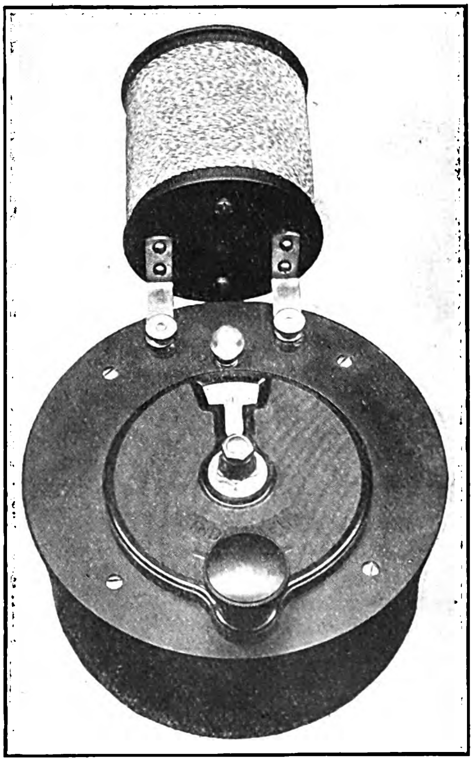
An entirely new type of meter, for use on A.C. of the ordinary supply frequencies, is also made by Messrs. Ferranti. This consists of the usual 1 mA. or 5 mA. moving-coil instrument combined with a bridge of four copper-oxide rectifiers; by this means it is possible to produce a simple meter sensitive enough to give full-scale deflection with no more than 1.5 mA. A companion instrument is made for voltage measurements, the resistance being 160 ohms per volt or, at a slightly higher price, 800 ohms per volt. These meters, owing to the limitations of the rectifier used in them, are at present only made in ranges up to 0.5 amp. or 10 volts, but as it is for low voltages and small currents that their superiority over the moving-iron instrument is chiefly valuable this limitation is not a very serious matter. In any case, the range can be extended by the use of transformers. They are calibrated in R.M.S. values, and so are strictly only accurate when used for pure sine-wave current; with this limitation, an accuracy of 1 per cent. is claimed. It is to be noted that the scale is far less cramped at the bottom end than is usual with A.C. instruments, the lowest reading that can conveniently be made being about 2 per cent. of full-scale reading, instead of the more usual 10 per cent. of the moving-iron ammeter. It is not, of course, possible to use these meters for high-frequency currents, nor will they read correctly on D.C.; but they can be relied upon between the limits of 25 and 100 cycles.

Burndept transmitters' wavemeter.

Wavemeters.

There were several wavemeters on view at Olympia, most of them being of the absorption type. The model made by Messrs. Burndept Wireless (1928), Ltd., was of especial interest to the short-wave transmitter in that a very small band of frequencies is covered by each swing of the condenser, so that a very high accuracy over a limited range is made possible. The permissible limits of working on the 20-metre band, for example, although small, spread over some twenty or thirty degrees of the scale, while the range covered by the whole swing of the condenser is from 20 to 23 metres. The wavemeter is supplied with two coils, one covering the range mentioned, and the other calibrated from 40 to 46 metres. The accuracy claimed is 0.05 per cent., and the price, with one coil, is £3 15s. A tiny Neon tube is incorporated for the purpose of indicating when resonance is reached.

The other wavemeters seen were designed for less specialised work, and consequently each swing of the condenser covered a much greater band of frequencies, giving greater convenience but much less accuracy. The usual ratio of wavelengths obtained, with one coil, at the two ends of the scale was about 3½ : 1. Both the Bowyer-Lowe and the Igranic wavemeters were designed in this way; the latter is purely an absorption wavemeter, while the former can be used as an absorption wavemeter but is also provided with a buzzer (externally adjustable) for use with a receiving set. Both these instruments are contained in screened boxes, and both are accurate to within 1 per cent. when supplied.



Igranic absorption wavemeter for all wavelengths.

A whole series of wavemeters is offered by Messrs. Dubilier, ranging from a simple

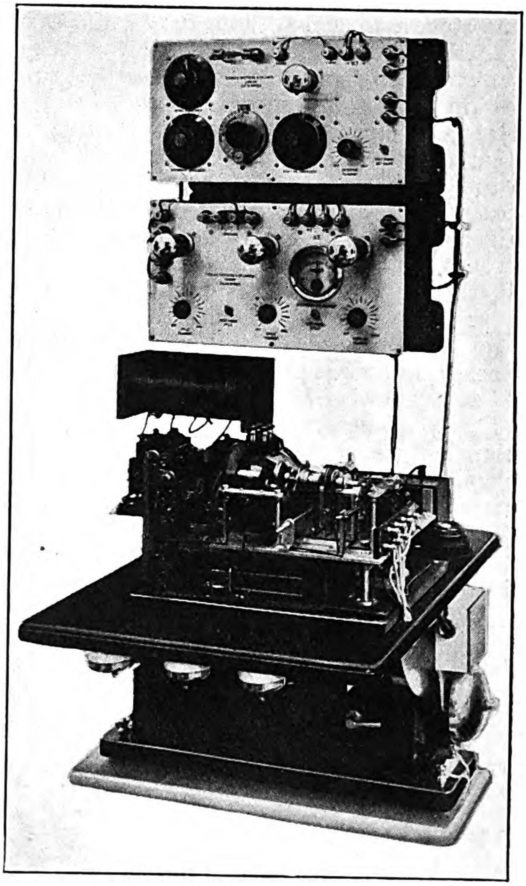
Other Exhibits.

In addition to laboratory instruments, there were a number of exhibits not primarily intended for broadcasting receivers. For example, there were on show a number of power transformers for supplying anode and filament current for public address equipment or gramophone reproducers for theatres and cinemas. Messrs. Partridge & Mee make a full range of such transformers, and express their willingness to design and make any non-standard model for special purposes. Messrs. Marconiphone have also a transformer of this type, and there is now a Marconi full-wave rectifying valve, the U8, suitable for providing the anode current for L.S.5a output valves. A new high-dissipation output valve, known as the L.S.6a, has also made its appearance; it is approximately equivalent to two L.S.5a's in parallel, but uses less filament current and costs only 5s. more than a single L.S.5a. A number of heavy-duty components were also on view on the stand of Messrs. R. I. & Varley, including intervalve low-frequency transformers rated for a primary current up to 15 mA. These are also available as push-pull models, and companion output transformers are also made. Heavy-duty smoothing chokes were in evidence on this stand, these having an effective inductance of 7 or 14 henrys, while carrying a D.C. load of 100 mA. For cases where larger direct currents than this have to be carried, the same makers have a choke of D.C. resistance 240 ohms in which the core has an adjustable air-gap to enable the effective inductance to be brought to the highest figure for each individual set of operating conditions. The figures given for this choke are these :—

No air-gap ; no D.C. ..	40 henrys
No air-gap ; 200 mA. D.C.	15 ,,
Max. air-gap ; no D.C. ..	27 ,,
Max. air-gap ; 200 mA. D.C.	23 ,,

For high-power receivers or small transmitters where the use of the mains is not convenient, it was noticed that nearly all the accumulator-makers were offering small high-tension cells rated at 5 to 10 ampere-hours capacity((1,000-hour rate), and able to withstand discharge-loads up to quarter or half an ampere, at very reasonable prices, ranging from 8s. to 12s. per 10-volt block.

Two novelties in the form of short-wave sets were noticed; one of these, the Igranic Screened-grid Neutrodyne, employs a stage of high-frequency amplification, the small residual capacity of the screened-grid valve being neutralised in the conventional manner. By this means the makers have been able to take advantage of the attractive figures of the screened-grid valve without incurring the oscillation troubles that the residual capacity (very high from the short-wave point of view) would otherwise cause. The amplification claimed for the stage is about three times, or about 50 per cent. greater than that attained in their receiver employing an ordinary valve. The other unconventional short-wave receiver is the Eddystone "Scientific Short-wave Three," in which a screened-grid valve is again used in the

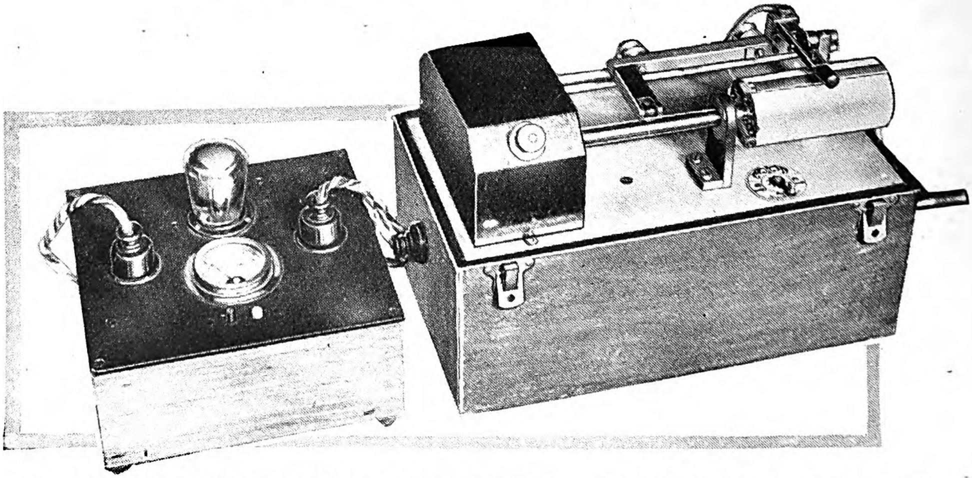

The Siemens auto-alarm, which keeps automatic watch for an alarm signal from vessels in distress.

high-frequency stage. In this case the grid-circuit of the first valve contains a high-frequency choke in place of a tuned circuit, and it is claimed that amplification is reduced very little by this device, while the ease of handling is very greatly augmented. No definite claim as to the amplification of the stage is made.

Perhaps the most fascinating piece of apparatus in the whole Show was the Auto-Alarm equipment shown on the stand of Messrs. Siemens Brothers. It is intended that this should be installed on ships which carry only one wireless operator, and it provides an automatic watch for the alarm signal (three 4-second dashes, with 1-second spaces) that precedes the S.O.S. The timing in this apparatus is performed by a small synchronous motor, driven by a tuning-fork, and it is normally adjusted to respond to dashes from 3½ to 4½ seconds in length, thereby allowing for the probable excitement of the operator transmitting the alarm signal. The output from a receiving set is applied to the instrument, but it does not respond to any but the pre-arranged signal. On the receipt of this, however, it closes a relay, which is normally used, we understand, to ring bells in the wireless room, the operator's cabin, and on the bridge. Should anything whatever go wrong with the receiver—if a connection breaks, or a valve burns out, for example—the bell rings to draw attention to the fault; the same thing occurs if the motor in the apparatus stops, or if the power supply either to it or the receiver fails.

We were informed that the equipment has been subjected to an official test, in which a certain number of false calls were permitted in a given time. We forget whether the false calls actually given during this period were one more or one less than half the maximum number permitted; in any case the test was passed with flying colours. Apparently heavy congestion of traffic, such as occurs especially after the period of idleness enforced by an S.O.S. call, will sometimes give rise to a false alarm, a number of overlapping signals from different transmitters occasionally simulating the three prolonged dashes within the limits of error permitted by the timing of the relays. The Auto-Alarm has not yet been given so human an intelligence that it can separate different transmitters by their note, as does the operator, so that a certain small percentage of false calls is inevitable.

Picture Broadcasting Apparatus.



Complete Fultograph picture receiving equipment, consisting of rectifying panel and clockwork-driven machine with synchronising equipment.

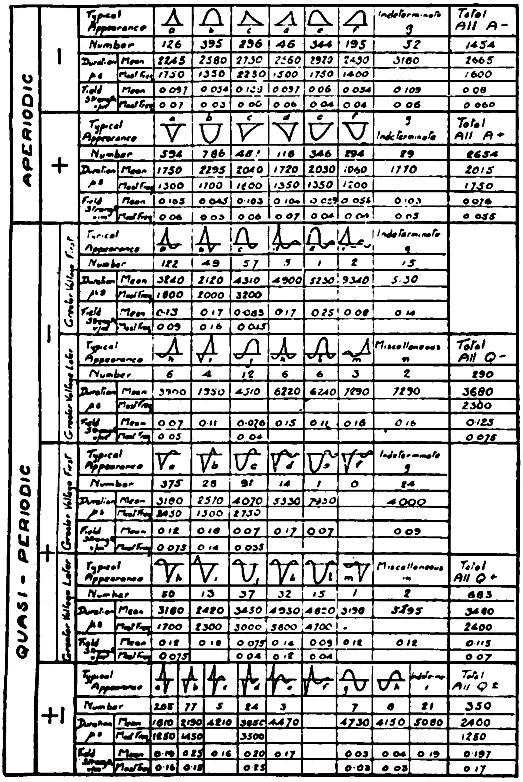
Present State of Knowledge of Atmospherics.

Paper by R. A. Watson Watt, B.Sc., F.Inst.P., A.M.I.E.E., read before Section A of the British Association meeting at Glasgow in Sept., 1928.

Abstract.

PERHAPS the most important paper of technical wireless interest at the recent British Association meeting was that given under the above title by Mr. R. A. Watson Watt, Superintendent of the Radio Research Station of the Department of Scientific and Industrial Research.

The paper reviewed our present knowledge of atmospherics, considering the subject from the point of view of data as regards the atmospherics themselves rather than that of their effects in wireless signalling, and is more concerned with results than with details of experimental methods. The author dealt with work on the waveform of atmospherics (as determined by observations with the cathode ray oscillograph), numerical incidence, directional observations (both by rotating frame aerial and pen recorder, and by cathode ray oscillograph), the intensity of the disturbance, and the range of atmospherics as determined by an extensive broadcast experiment.



APERIODIC	−	Typical Appearance		a	b	c	d	e	f	Indeterminate g	Total All A−
		Number		126	395	236	46	344	195	32	1454
		Duration μs	Mean	2245	2580	2730	2560	2970	2430	3180	2665
			Most Freq.	1750	1350	2230	1500	1750	1400		1600
		Field Strength v/m	Mean	0·091	0·034	0·130	0·097	0·06	0·034	0·109	0·08
			Most Freq.	0·07	0·03	0·06	0·06	0·04	0·04	0·06	0·060

APERIODIC	+	Typical Appearance		a	b	c	d	e	f	g Indeterminate	Total All A+
		Number		594	786	481	118	346	294	89	2654
		Duration μs	Mean	1750	2295	2040	1720	2030	1060	1770	2015
			Most Freq.	1300	1700	1600	1350	1350	1200		1750
		Field Strength v/m	Mean	0·105	0·045	0·103	0·104	0·059	0·056	0·103	0·076
			Most Freq.	0·06	0·03	0·06	0·07	0·04	0·04	0·05	0·055

QUASI-PERIODIC	−	Greater Voltage First	Typical Appearance		a	b	c	d	e	f	Indeterminate g	
			Number		122	49	57	5	1	2	15	
			Duration μs	Mean	3840	2120	4310	4900	5230	9340	5130	
				Most Freq.	1800	2000	3200					
			Field Strength v/m	Mean	0·13	0·17	0·083	0·17	0·25	0·08	0·14	
				Most Freq.	0·09	0·16	0·045					

QUASI-PERIODIC	−	Greater Voltage Later	Typical Appearance		h	i	j	k	l	m	Miscellaneous n	Total All Q−
			Number		6	4	12	6	6	3	2	290
			Duration μs	Mean	3300	1950	4510	6220	6240	7290	7290	3680
				Most Freq.								2300
			Field Strength v/m	Mean	0·07	0·11	0·076	0·15	0·11	0·16	0·16	0·125
				Most Freq.	0·05		0·04					0·078

QUASI-PERIODIC	+	Greater Voltage First	Typical Appearance		a	b	c	d	e	f	Indeterminate g	
			Number		375	28	91	14	1	0	24	
			Duration μs	Mean	3160	2510	4070	5330	7930		4000	
				Most Freq.	2450	1500	2750					
			Field Strength v/m	Mean	0·12	0·18	0·07	0·17	0·07		0·09	
				Most Freq.	0·075	0·14	0·035					

QUASI-PERIODIC	+	Greater Voltage Later	Typical Appearance		h	i	j	k	l	m	Miscellaneous m	Total All Q+
			Number		50	13	37	32	15	1	2	683
			Duration μs	Mean	3160	2420	3450	4930	4620	3190	5295	3460
				Most Freq.	1700	2300	3000	5800	4700	·		2400
			Field Strength v/m	Mean	0·12	0·18	0·075	0·14	0·09	0·12	0·12	0·115
				Most Freq.	0·075		0·04	0·12	0·04			0·07

QUASI-PERIODIC	±1	Typical Appearance		a	b	c	d	e	f	g	h	Indeterminate i	Total All Q±
		Number		205	77	5	24	3		7	8	21	350
		Duration μs	Mean	1610	2190	4210	3850	4470		4730	4150	5080	2400
			Most Freq.	1250	1450		3500						1250
		Field Strength v/m	Mean	0·19	0·25	0·16	0·20	0·17		0·03	0·04	0·19	0·197
			Most Freq.	0·16	0·18		0·25			0·03	0·03		0·17

Fig. 1.

Waveform of Atmospherics.

In connection with the work on waveform a slide, here reproduced as Fig. 1, shows the characteristic shapes and magnitudes of a sample group of 8,000 atmospherics delineated in South-east England in autumn. Fig. 2 gives scale drawings of the most frequently occurring classes, and indicates their percentage frequency, while Figs. 3 and 4 respectively give similar results for Khartoum (observations in the month of April), and Western Australia (observations in March).

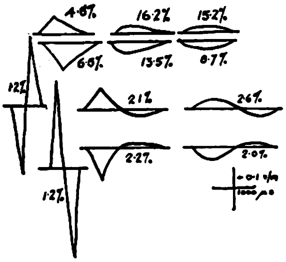


Fig. 2.—*England.*

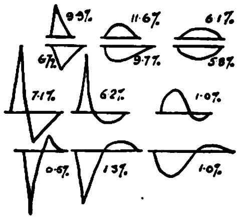


Fig. 3—*Sudan.*

Mean waveforms of main types of atmospherics.

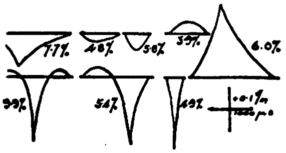


Fig. 4.—*Australia.*

The majority appear sensibly aperiodic—*i.e.*, no reverse field reaching 4 millivolts-per-metre occurred with a period comparable to some small multiple of the time occupied by the main field change. It is not yet clear whether these aperiodic forms are due to a wide separation in time between the period of strong acceleration and that of deceleration in the original discharge, or to selective dissipation.

Although the data are not adequate for a general survey of the geographical and seasonal variations of the characteristic waveform, the information available indicates that the mean peak field-strengths fall off with increasing latitude, while the mean duration of individual atmospherics normally increases with latitude. The mean rate of change of field—on which the interferent power of the atmospheric largely depends—therefore increases very steeply with decrease of latitude, There is a suggestion from the data that the negative aperiodic form is more universal in character than are any of the other main classes.

As regards the effects of such relatively slow field changes in producing the interference actually experienced in wireless signalling, it is pointed out that while the steep initial slopes shown would suffice to produce considerable E.M.F.'s in receiving apparatus, further explanation is to be found in the fine structure superposed on these fundamental forms. This is particularly so in the tropics and in the dark hours. Examples were given by slides of such forms taken at Khartoum, one of which is given in Fig. 5. In two cases taken at random, these ripples showed a 4,000-metre wavelength, and a field strength of 10 millivolts-per-metre—some 4,000 times as great as would be required for wireless signals.

Numerical Incidence of Atmospherics.

The circuits used for waveform delineations were also convenient, with very slight modification, for determination of the relative frequency of occurrence of atmospherics having peak field-strengths between specified limits. Fig. 6 shows the numbers of atmospherics per minute which passed amplitude limits up to 500 m.v./m. at Aldershot, Helwan and Khartoum. As an adequate first approximation, a law of the form $NE^2 = a$ constant is suggested by the author.

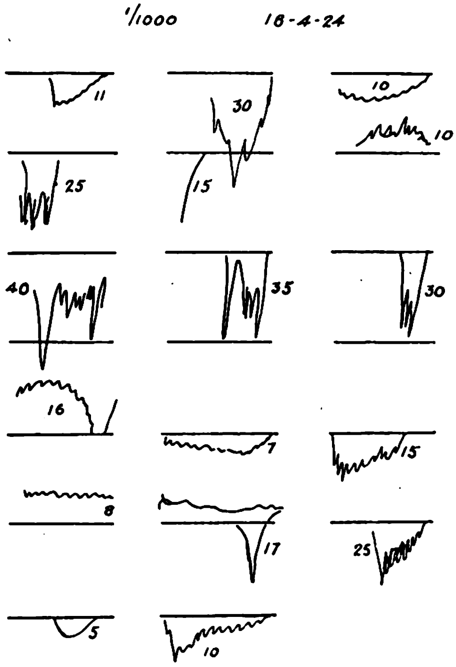


Fig. 5.

By a further modification of the same apparatus it was possible to determine the relative frequency of peaks so small as to be just over the limits of perception in the method used. This was first done in tropical waters (in conjunction with officers of H.M. Signal School), and the results, although then alarming, were found to be consistent with a large number of similar counts made at land stations. As examples, average numbers at Helwan (Egypt) were approximately 100 per second at 0800 G.C.T., 250 at 1800, and 200 at 2000. At Khartoum these numbers were almost always exceeded and counts up to 1,200 and 1,500 per second were not infrequent in the dark hours.

Combination of data on frequency of incidence and of the durations of individual impulses show that in the dark hours in the tropics it is a very rare occasion when no considerable voltage from atmospherics exists in the aerial. These observations explain the acute disturbance experienced in the tropics and the complete inadequacy of anti-atmospheric devices suggested in the past.

Directional Observations.

The directional work described in the paper is of considerable importance in correlating areas of atmospheric production with meteorology.

After preliminary work by aural methods on the mean direction of arriving atmospherics, pen-writing recorders were designed to supply more complete data of this nature.† A solid diagram showing the mean hourly duration of atmospherics at Aboukir for each month of a three-years' period was exhibited at the reading of the paper. This model shows that throughout the year a predominant stream is arriving from nearly south at noon G.C.T. This swings westwards throughout the afternoon, the swing being greatest near the autumnal equinox and least near the vernal equinox. This westward swing diminishes about 1700 G.C.T. when atmospherics from the North-east begin to predominate, these becoming more northerly until near noon, when the southern stream becomes most important. The swing of the Northerly stream is greatest near the spring equinox, and is not traceable in the records near the autumn equinox.

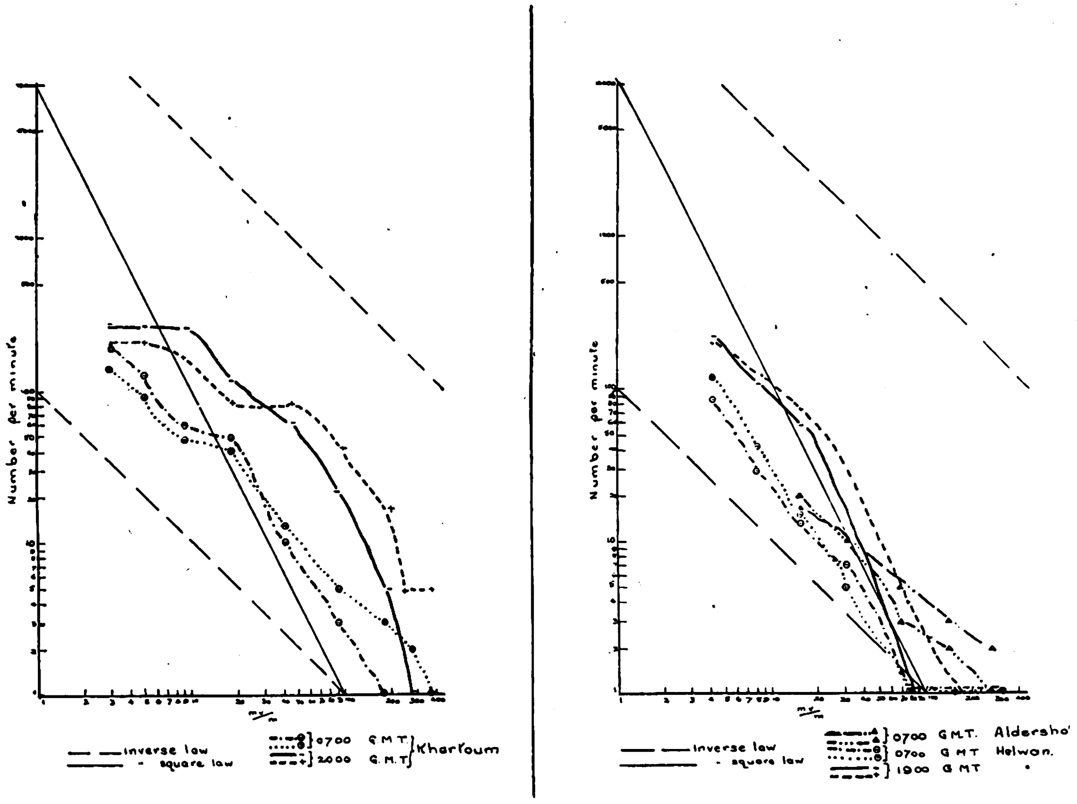
From simultaneous plotting of observations from all the recorder stations, a world map of travel of the chief atmospheric sources was prepared and exhibited at the reading of the paper. The predominant source normally lies in a summer afternoon or evening, so that the cum-solar travel, previously inferred by various workers, is substantiated and amplified by the more complete data given here. The inactivity of the Pacific Ocean, and the activity of mountainous regions as atmospheric-producing areas are also shown in the map.

While the recorders referred to deal with average values, observations on the direction of arrival of individual atmospherics have become possible by the use of the cathode-ray oscillograph. The principle of this arrangement has already been described.*

---

† See *E.W. & W.E.*, April, 1926.

* See *E.W. & W.E.*, April, 1926.



No. of Atmospherics per minute of Field Strengths shown.
Aldershot, Helwan, Khartoum.

Fig. 6.

A very complete test of the method was recently made possible by collaboration with the Post Office during the summer of 1927, when apparatus was installed at the Radio Research Station (Ditton Park, Slough) and at the P.O. Radio Station at Cupar, Fifeshire. The observers were in direct telephonic communication with each other, so that practically complete certainty was attained as to the identity of the particular atmospheric whose direction was observed at each end of this base line. A number of slides were exhibited showing the distribution of places of origin on various days in June and July, 1927.

On the whole it is concluded that the picture of thunderstorm activity given by the maps shown at the lecture—yielded each by approximately 30 minutes total time of two observers—is of an adequacy comparable to that given by the daily weather reports.

From some of the measurements it is deduced that the peak field strength of the atmospheric component at 10 kc. (to which the frame aerials were tuned) received from thunderstorms 3,000 to 5,000 kilometres distant, is approximately inversely proportional to distance, but further subject to strong dinmal variation due to attenuation.

Intensity of Disturbance.

Curves of the integrated intensity of the disturbance at each hour of the day from the directional pen-writing recorder at Aldershot for the years 1922 to 1924, are shown in Fig. 7. These reveal a principal maximum about midnight and a principal minimum between 10 a.m. and noon local time. A secondary minimum becomes prominent about 14 hours in summer, but fails to appear in midwinter. The main deductions from the intensity curves are shown to be in good agreement with the world map distribution already described.

The Range of Atmospherics.

An interesting test of this subject was organised by the Royal Meteorological Society, with a group of observers distributed throughout Western

Europe, North Africa and Madeira. By the co-operation of the B.B.C., advance typescript copies of talks to be broadcast were supplied for circulation to the observers. At the time of the actual broadcast the observers marked the syllables and spaces overlaid by atmospherics, returning the marked typescript to a centre for analysis and reduction. An example of the results (shown in a slide at the reading of the paper) reveals that the streams of atmospherics are not peculiar to each station, coinciding only at random moments, but that a single disturbance makes itself felt over the greater part of the observing network at once. Check bearings were also taken at the Radio Research Station on the individual atmospherics disturbing the broadcast talks, and found to pass through sources as indicated by joint recorder location. It could thus be concluded that the atmospherics disturbing the broadcast had proceeded from these sources. The results gave sources on many of these occasions at great distances.

The French belief in the short range of atmospherics has been encouraged by apparent matching of curves of atmospheric strength and of wind velocity at the same place. A comparison made between the French atmospherics record and one at the Radio Research Station showed that the time of incidence of the chief features agreed within the accuracy of measurement of the two systems more closely than did the features of the French atmospheric of wind records.

Terrestrial Magnetism Influences.

Comparison of the atmospherics record on a long wave intensity recorder against that of magnetic elements on the occasion of a very severe magnetic storm in 1926, showed that when the vertical component of the earth's field assumed high values, the atmospheric disturbance rose to some four times normal. This type of effect must be investigated more fully as the quantitative recording of atmospherics proceeds.

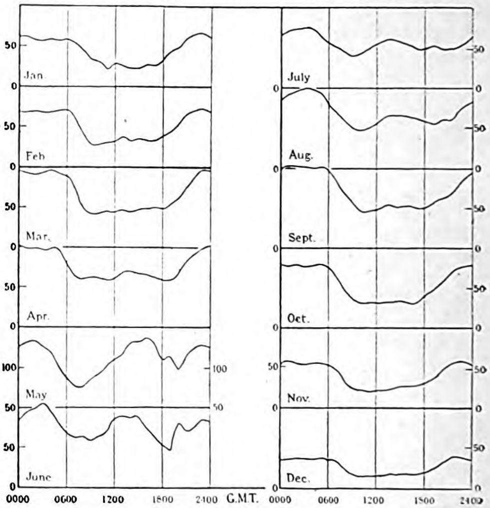
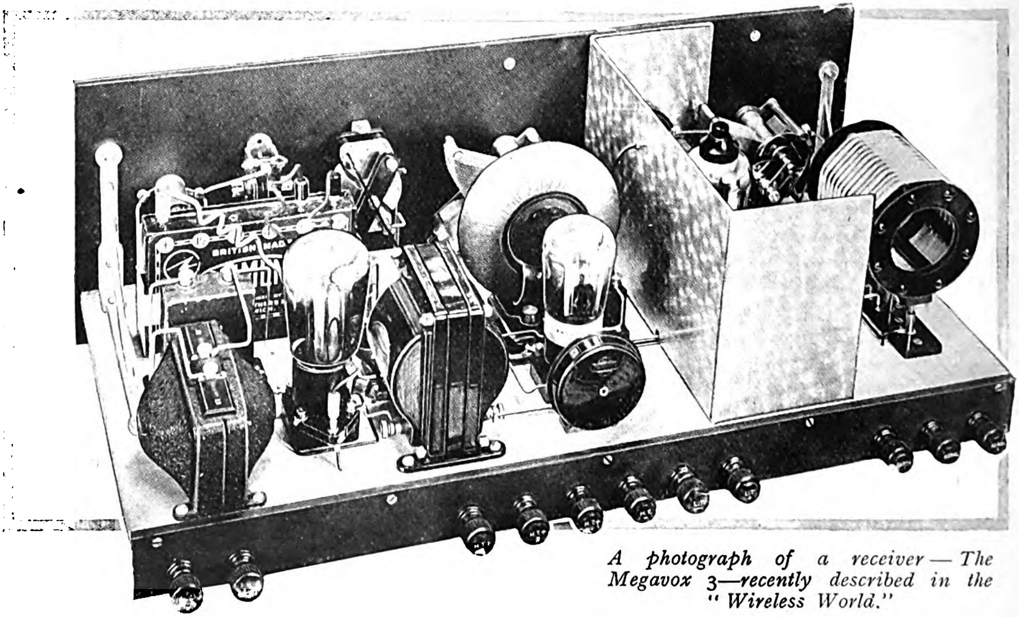


Fig. 7.—*Diurnal variation of intensity.*

A New Screened Grid and Pentode Receiver.



A photograph of a receiver — The Megavox 3—recently described in the "Wireless World."

A Method of Calibrating a Low Frequency Valve Generator with a Single Frequency Standard Source.

By T. S. Rangachari, M.A.

(Indian Institute of Science, Bangalore, India.)

A NUMBER of articles have appeared in wireless journals dealing with the construction of a valve-generator for audible frequencies, but methods of calibration have been rarely described. A fairly well-known method of calibration is that of comparison with the fundamental and harmonics of a standard valve-maintained tuning fork. In the application of this method it is necessary that the audio-generator must be capable of continuous variation of frequency so that it may be tuned to the harmonics of the fork for comparison (see for example Sylvan Harris, *Proc. Inst. of Rad. Eng.*, 1926, 14, p.213). The frequency for any given setting of the audio-generator is then read off from a calibration graph. In many cases where an audio-frequency generator is required it is superfluous to make it continuously variable. In many physical science laboratories, for instance, it is enough if the source is variable in steps by varying the tuning condenser in blocks. In such a case the problem of calibration becomes that of determining accurately the frequency of the generator at a given setting by means of a given standard valve-maintained tuning fork. The above method of comparison with selected harmonics of the fork now fails since one can no longer tune the audio-frequency generator continuously. Below is given a method which makes it possible to compare the frequency of the audio-generator at any setting of its condenser with that of the fundamental of a standard valve-maintained tuning fork.

Principle of the Method.

The principle of the method may be explained with reference to Fig. 1, which shows a non-inductive variable resistance R and an inductive coil L, whose resistance is R_L arranged in series. The procedure is as follows: Apply at AB the output from the tuning fork source whose frequency f_1 is known. Adjust R till the voltage drop V_1 across R equals the drop V_2 across the coil with the help of a thermionic voltmeter. The thermionic voltmeter is arranged such that it does not apply any load when connected either to the resistance or to the inductance. Note the value R_1 of the variable resistance required to balance the voltage drop across L.

Then $$R_1^2 = (2\pi f_1 L)^2 + R_L^2 \qquad .. \quad (1)$$

Now apply the output from the generator. Let its frequency which is unknown and which is to be determined be f_2. Adjust the resistance R till balance is secured. Let R_2 be the resistance required for balance.

Then $$R_2^2 = (2\pi f_2 L)^2 + R_L^2 \qquad .. \quad (2)$$

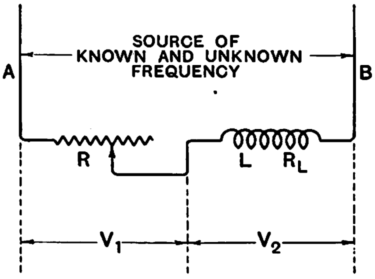


Fig. 1.

From (1) and (2)

$$\frac{R_1^2 - R_L^2}{R_2^2 - R_L^2} = \frac{f_1^2}{f_2^2}$$

or $$f_2 = f_1 \times \sqrt{\left[\frac{R_2^2 - R_L^2}{R_1^2 - R_L^2}\right]} \qquad .. \quad (3)$$

All the terms on the right-hand side of the equation (3) are known. Hence f_2 is determined.

Practical Considerations.

In practice, R is made to be of the order of a few thousand ohms by suitably choosing the value of L. R_L, which is the D.C. resistance of the inductance coil is of the order of tens of ohms, so that any slight error in the determination of R_L does not affect the result appreciably.

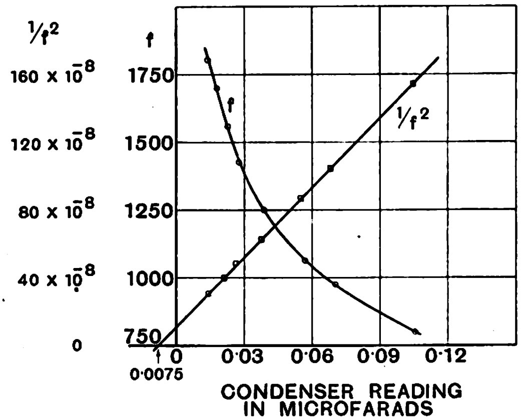


Fig. 2.

The thermionic voltmeter is of the anode bend type with negative grid bias, so that it does not apply any load when connected to the circuit. It is necessary that it should be arranged to be sensitive, but it need not be calibrated since this is a balance method. The thermionic voltmeter used in this method had a unipivot galvanometer, whose figure of merit was 4 divisions per microampere, in the anode circuit, the D.C. being balanced by a potentiometer. A calibration with A.C. showed a deflection of about 40 scale divisions per 0.15 volt R.M.S., provided the applied voltage is greater than 0.3 volt R.M.S.

The sensitivity of this method may be illustrated by the following data for an actual case. Using a standard valve-maintained tuning fork of 800 cycles per second, a resistance (R_1) of 3,035 ohms was found necessary to balance the voltage drop across the inductance coil. Since the impedance of L at 800 cycles per second is thus about 3,035 ohms, it can be calculated that it changes by nearly 4 ohms per cycle change of frequency. Now, a change of 4 ohms in R was found to alter the deflection by 4 divisions. This deflection depends both on the sensitivity of the thermionic voltmeter and on the input power, and can be increased by increasing both. Thus the arrangement could be adjusted for balance to an accuracy sufficient for many purposes.

Some Results.

This method was adopted to calibrate a valve generator from 300 cycles per second to 3,000 cycles per second, from which the following result is taken. The valve generator consisted of a master oscillator and a power amplifier, but the method can be applied to any type of generator. Table I shows the frequency of the generator thus determined at the various settings of its condenser. Fig. 2 shows the calibration curve, as also the relation between the condenser setting (C) of the generator and the reciprocal of the square of the frequency $\left(\frac{1}{f^2}\right)$, which is nearly a straight line, whose intercept on the condenser axis gives the self-capacity C_0 of the oscillator coil. As a check, the ratio $\frac{1}{f^2} \div (C_0 + C)$ is calculated and given in the last column of Table I and is found to be fairly constant.

TABLE I.

Oscillator Condenser C Microfarad.	Frequency f Cycles per Second.	$\frac{1}{f^2} \div (C_0 + C)$.
.1065	800	13.71×10^{-6}
.0710	969	13.57×10^{-6}
.0570	1,065	13.67×10^{-6}
.0380	1,263	13.78×10^{-6}
.0285	1,423	13.72×10^{-6}
.0225	1,564	13.63×10^{-6}
.0180	1,697	13.61×10^{-6}
.0150	1,800	13.73×10^{-6}

One advantage of this method of calibration is that there is no necessity to calibrate the condensers in the oscillator at all. For, whatever might be the true value of the condenser, the frequency is exactly determined at its face value. A sufficiently large number of settings could be thus calibrated and so there is no need for extrapolation.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

The Transmitting Station actually sends out Waves of one definite frequency but of varying amplitude.

To the Editor, E.W. & W.E.

SIR,—In the August number of *E.W. & W.E.*, Professor Howe in his editorial states: "The transmitting station actually sends out waves of one definite frequency but of varying amplitude," and goes on to state that, "such a modulated wave has the same effect on the *receiver*[*] as waves of constant amplitude, but of varying frequency." For this reason receivers have to be designed to accommodate a band of frequencies.

From the way it is put I suspect Professor Howe is amusing himself by creating a controversial point, and although he may be able to justify such a statement, it is worded in such a way as to cause confusion in minds less agile than his own, and the statement as a whole is very open to criticism.

To commence with, one gathers that we have an irreversible effect, namely, a single wave radiated, giving rise to the effect of a spectrum at the receiver, in which case the characteristic of the transmitter would only need to be capable of accommodating a single frequency. But the spectrum effect is in evidence just so soon as modulation is impressed and hence the high frequency system of the transmitter, no less than the receiver, must be capable of accommodating the required band of frequencies. This is a point often overlooked, probably because of this method of visualising a modulated wave.

One of the difficulties of transmitting broadcast modulation on the longer wavelengths is because the aerial characteristic is not able to take in the wide band of frequencies involved, and hence artificial damping has to be added to make it possible.

A further impression one gets from Professor Howe's statement is that a modulated wave has only the *effect* of a spectrum and that the individual frequencies are intangible. But they are very real, and with the help of a very selective receiver, such as is used for commercial service C.W. work, it is easily possible to isolate any desired frequency from a modulated signal. Further, by the same selective receiver, one can prove that none of these individual frequencies varies in amplitude.

Further evidence of the existence of a spectrum is found in very short wave propagation. One gets selective absorption of certain waves due to the wave frequency coinciding with the collision period of ions in the upper layer and a modulated wave suffers severe distortion because groups of frequencies are "dropped out" during the passage of the wave. In fact, we have such concrete evidence in practice that a modulated wave does *not* consist of a single frequency but a band of frequencies, that it would appear more logical to talk of it as such. That is to say, think of modulation not as varying the amplitude of the original carrier wave (which it does not do), but as giving rise to a new group of frequencies, the whole forming a spectrum.

The heterodyning of these waves certainly forms a synthesis wave whose envelope conforms to the modulating waveform, but the pictorial conception of this wave does not assist our knowledge of what is happening.

It is agreed, I think, that whether one talks about the synthesis wave or the spectrum one means the same thing, and no doubt the theory of modulation could be argued out on an amplitude instead of a frequency basis. But surely one ought to be consistent, and having adopted the idea of the frequency band as being easier of solution stick to it, and give up the idea of a modulated wave as a single frequency varying in amplitude. Anyway, certainly not talk of a single frequency being radiated and a group being received.

A. W. LADNER.

Danbury, Essex.

[We would point out that Mr. Ladner misquotes us; we did not say that "such a modulated wave has the same effect on the receiver as waves of constant amplitude, but of varying frequency." What we said was, "as waves of constant amplitude but of different frequencies." But apart from this, we are quite impenitent. Imagine a being endowed with such powers that he could actually see the electric current rushing up and down the transmitting aerial at 2LO; what would he see? He would see an alternating current of which each pulse or alternation occupied the same time to a high degree of accuracy, or in other words, the number of alternations per second would be unchanging. He would notice, however, that the magnitude of the current differed from pulse to pulse. Surely he would say that it was a current of one definite frequency but of varying amplitude. To arrive at any other conclusion our imaginary being would have to be endowed with the powers of a harmonic analyser. The upper atmosphere and a tuned circuit behave as they do because they possess this analytic power.—G.W.O.H.]

Short-wave Fading.

To the Editor, E.W. & W.E.

SIR,—I was very interested to read the short article by Mr. T. S. Rangachari from Bangalore, India, on the subject of short-wave fading, in which he gives illustrations of both slow and rapid fading from the Dutch station, PCJJ, on 30.2 metres.

I have made careful observation on the European and Australian short-wave broadcasting stations, during the last nine months in Canada, and from the re-broadcasting standpoint, the major trouble would appear to be due to independent fading of the carrier wave and the side bands. Regular fading, such as Mr. Rangachari mentions, can, to a certain extent, be looked after, but I would be very interested to hear of any possible solution to the side band fading, which we have encountered here, and which tends to show no regular characteristics.

---

[*] The italics are mine.—A.W.L.

Toronto, P. H. Dorté,
17th Sept., 1928. Chief Engineer,
Trans-Canada Broadcasting Co.

Polar Diagrams Due to Plane Aerial Reflector Systems.

To the Editor E.W. & W.E.

Sir,—There are two points on which I should like to comment in the article "Polar Diagrams Due to Plane Aerial Reflector Systems" in your October issue.

(1) The polar diagrams of Figs. 5 and 6 appear to show that the field strength in the direction $\psi = 90$ deg. has a value about two-thirds of the maximum value in the horizontal plane. Now $\psi = 90$ deg. is the end on direction for all the wires of the system, and I have always understood that the radiation from a wire in that direction was zero, and should therefore be zero for the whole system. The original expression given for the field strength contains a term $\cos \frac{(\beta \cos \psi)}{\sin \psi}$, which appears later as $\cos \frac{(\beta \sin \psi)}{\cos \psi}$. This may be a printer's error, or it may account for the result. If however the value of the radiation shown in the direction $\psi = 90$ deg. is correct, a direct physical explanation would be interesting.

(2) The three-quarter wave aerial chosen as an example is one which gives the maximum radiation at a high angle, and the reflector at $\frac{1}{4}\lambda$ spacing is only correct for aerials giving the maximum radiation horizontally ($\psi = 0$). In the vertical plane, the more sharply directional horizontally the aerial is the more effective such a reflector system will be. The system can be made thus sharply directional by making each aerial a wavelength or more in height, whilst arranging that all the radiating parts of the aerial are oscillating in the same phase. For an aerial 2λ high neglecting the effect of the earth (or 1λ high assuming a perfectly conducting earth) the theoretical maximum value of the field strength of the back radiation is about 5 per cent. of that for the maximum forward radiation. This is a much smaller value than that shown in Fig. 5. Greater heights of aerial and reflector system would reduce it still further.

E. Green.

Chelmsford.
October 1st, 1928.

Sir,—I have to thank Mr. Green for pointing out the clerical error in the cosine term. The correct expression is that used in computing the polar diagram, namely

$$\frac{\cos (\beta \sin \psi)}{\cos \psi}$$

With regard to the radiation at angles of 90 deg., I must concede that further consideration is needed in this matter. It is quite possible that some confusion has arisen in evaluating the products and quotients of sine and cosine terms as ψ approaches 90 deg. and an expression $\frac{0}{0}$ is obtained. I am inclined to admit that an error has been made. The main purpose of the article, however, was to show that even under the usual conditions of correct phrasing and amplitude of reflector current, the assumption so frequently made by Radio Engineers who have not given the matter detailed consideration that a reflector cuts off back radiation at all angles with the horizontal, is far from correct.

I agree with the main contention contained in the second part of Mr. Green's letter that low angle back radiation is almost completely suppressed by the ideal reflector. This at once follows from the application of the reflector multiplying factor $\sqrt{2(1 \div \cos \theta)}$, or its more convenient form $\frac{2 \cos \theta.}{2}$ The practical reflector, however, is far from ideal. Moreover, high angle radiation from an aerial such as Mr. Green mentions is not negligible.

T. Walmsley.

Ealing, W.5.

Output Measurements on a M/C Speaker.

Sir,—We wish to thank Dr. McLachlan for his letter in the October issue, and are pleased to note that he has found similar diaphragm resonances to those found by us. We must confess, however, that with the exception of the article in the *Wireless World* of 8th August, when, of course, our contribution was in the Editor's hands, we have been unable to find reference to the theoretical or practical effects of elasticity in the diaphragm or supports.

In the equivalent circuit, Fig. 10g, as pointed out, the reactance in the loud speaker circuit is admittedly drawn as a coil and may admittedly prove misleading, but, of course, is actually a complex reactance varying with frequency, as stated elsewhere in the text.

We were unable in this particular case to trace any resonances other than the main one, and do not believe that this was due to frequency gaps in the curves, since the change in impedance was carefully followed on the bridge, and readings were taken wherever rapid alteration took place.

In regard to the value of the motional impedance, it is hoped that more work will shortly be done on this and confirming or disproving results will be available.

We agree with the remarks that great care must be taken for suitable clamping at the high frequencies.

N. R. Bligh,
H. A. Clark.

London.

ERRATUM.

In the letter signed by Dr. N. W. McLachlan in the October number, the reference to "*a fifth*" should have read "*one half.*"

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

ÜBER DIE BESTIMMUNG DES GÜNSTIGSTEN AUSSTRAHLWINKELS BEI HORIZONTALEN ANTENNEN (Determination of the optimum projection angle for horizontal aerials).—Meissner and Rothe. (*Elektrot. u. Masch : bau, Radio Supp.*, No. 9, 1928, pp. 81–83.)

Describes tests with a parabolic reflector, rotatable about a horizontal axis, using wavelengths of 20 and 15 metres. The author concludes that such constructionally difficult reflectors can be dispensed with, since the most effective projection is nearly parallel to the earth, and this can be accomplished more simply by horizontal aerials and reflectors. For previous papers see Abstract for January and February.

ÜBER DAS VERHALTEN DER RADIOTELEGRAPHISCHEN WELLEN IN DER UMGEBUNG DES GEGENPUNKTES DER ANTENNE UND ÜBER DIE ANALOGIE ZU DEN POISSONSCHEN BEUGUNGSERSCHIENUNGEN (The behaviour of radiotelegraphic waves in the neighbourhood of the antipodal point of the antenna, and the analogy to the Poisson diffraction effect).—J. Gratsialos. (*Ann. d. Physik*, 16th August, 1928, V. 86, pp. 1041–1061.)

The author's mathematical development (prompted by Sommerfeld) leads to the conclusion that at the antipodal point there must be a concentration of electromagnetic energy. This result is compared with the Poisson diffraction effect, and a great similarity found. No attention is paid to the Heaviside Layer.

L'ÉTAT MAGNÉTIQUE DE LA TERRE (The Earth's Magnetic Condition).—J. Granier. (*Q.S.T. Franç.*, September, 1928, pp. 43–46.)

A short survey of present ideas and methods of research on terrestial magnetism and telluric currents, both of which have—as the author points out—a certain influence on the propagation of e.m. waves.

CONCERNING LUNAR EFFECTS ON ELECTROMAGNETIC WAVES.—Greenleaf Pickard. (*Q.S.T.*, Aug., 1928, V. 12, p. 20.)

The author criticises a recent article (*ibid.*, June, 1928, p. 33) in which C. E. Paulson deduces, from observations (over one month only) on the evening strength of 32.77 m. signals, that the plane-polarised rays of moonlight have an effect on the propagation of radio waves. He shows that Paulson's curves (showing minimum strength at new moon and maximum at full) can be correlated with sun-spot and magnetic field variations, and points out that full moonlight has less than one hundred thousandth the intensity of sunlight and is in addition only feebly polarised. He also mentions that he personally would require at least two years' reception data (instead of one month's) before deciding that a lunar effect existed.

THE PROPAGATION OF SCHRÖDINGER WAVES IN A UNIFORM FIELD OF FORCE.—G. Breit. (*Phys. Review*, August, 1928, V. 32, pp. 273–276.)

Author's abstract: The phase difference between a Schrödinger wave refracted by a uniform field of force and the primary wave is calculated. . . As the wave length increases, the phase difference decreases, reaches a minimum and then increases again. It is suggested that the intensity of some crystal reflections should vary anomalously as a result.

FADING ON SHORT WAVES AT LONG DISTANCES.—E. Gherzi. (*Q.S.T.*, June, 1928, V. 12, pp. 31–32.)

Conclusions based on 12 months' observations near Shanghai on wavelengths from 20 to 100 metres over distances varying from 800 to 10,000 km. Over the long distances, periodic fading ("twinkling") was always noticed, the period being of the order of 10 seconds. The writer attributes this to oscillations of the lower layers of the atmosphere, depending for period on thickness, density and mean temperature. Observations on the vortex period of typhoons lead him to conclude that the oscillation period of the entire troposphere is not far from this value of 10 seconds.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

DIE ERHALTUNG DER ERDLADUNG DURCH DEN BLITZSTROM (The Maintenance of the Earth's Charge by Lightning Currents).—A. Wigand. (*Phys. Zeitschr.*, V. 28, pp. 65, 211, 260, 261.)

The writer estimates the average quantity of electricity in a flash as about 50 coulombs. There are about 100 flashes per second for the whole earth (according to Brooks' estimate). He considers that the proportion of these in the right direction is just about enough to maintain the earth's charge in face of the 1,400 A. vertical conduction current.

WIRKUNG EINES BLITZSCHLAGES (The Effect of a Lightning-stroke).—F. Janetzky. (*E.T.Z.*, 13th September, 1928, p. 1376.)

Referring to Binder's article (*see* July Abstracts) the writer describes the destructive effect of a stroke on a certain lightning conductor, made of copper 6.5 mm. in diameter.

A NEW ARRANGEMENT FOR SHOWING THE DIURNAL VARIATION IN THE INTENSITY OF THE EARTH'S SURFACE CHARGE AT A GIVEN PLACE.—F. Sanford. (*Science*, 20th July, 1928, V. 68, p. 64.)

Electrometer records during seven years have shown both a solar and a lunar diurnal variation varying with the seasons (much greater at equinoxes than at solstices) which is not due to temperature, illumination or atmospheric pressure and which is sometimes greatly disturbed by solar activity and by auroras. The author has attributed this variation to the inductive effect of the electric charges of sun and moon upon the earth's charge, but other workers have contested this and attributed the effect to other causes, the most plausible explanation being that it is somehow due to a diurnal variation in atmospheric conductivity, due to penetrating radiations or other causes. The author now quotes new tests to prove that the variations are entirely independent of atmospheric conductivity, that they are of electrostatic nature, and that (since the solar effect is several times as great as the lunar) they are not due to gravitational tides.

RADIO RECEPTION AND NORTHERN LIGHTS. (*Science*, 20th July, 1928, V. 68, p. x.)

A paragraph based on a report by F. P. Ubrich summarising the results of five years' observations in Alaska, which says: " . . . in general, the condition of the earth's magnetic field is no index of the quality of radio reception." The aurora occurs in greatest brilliancy on magnetically disturbed days, but " observations seem to indicate that good radio reception is very much more apt to occur than poor reception, during a bright or faint aurora."

SUR L'ORAGE MAGNÉTIQUE DU 7 AU 8 JUILLET, 1928 (The Magnetic Storm of 7–8th July, 1928).—Ch. Maurain. (*L'Onde Élec.*, August, 1928, pp. 363–364.)

Some magnetic records and details of this storm, described as the most violent for several years.

ZUR FRAGE DER PERIODIZITÄT DER SEISMISCHEN UND VULKANISCHEN ERSCHEINUNGEN (The periodicity of seismic and volcanic phenomena).—W. B. Schostakowitsch. (*Abstract in Phys. Berichte*, 15th August, 1928, p. 1589.)

A correlation between earthquakes and sunspot activity.

PROGRESSIVE LIGHTNING.—C. V. Boys. (*Nature*, 1st September, 1928, V. 122, pp. 310–311.)

A pair of photographic lenses carried on a rapidly revolving disc gave photographic records of a weak flash, showing that the flash started at the ground, and almost immediately after started also in the length next the cloud. The flash then travelled from both these parts and finished in the middle about 1/7,000th sec. later. The author gives this result, obtained with his comparatively slowly moving pioneer apparatus, as an indication of the possibilities of the method of oppositely moving images.

SOME RECENT WORK ON THE LIGHT OF THE NIGHT SKY (Part I).—Rayleigh. (*Nature*, 1st and 8th September, 1928, V. 122, pp. 315–317 and 351–352.)

THE AURORA AND ITS SPECTRUM.—J. C. McLennan. (*Proc. Roy. Soc.*, September, 1928, V. 120A, pp. 327–357.)

This Bakerian Lecture forms a survey of our present knowledge, based on the already published work of various workers, including the author, and on recent work of the latter. The identity of the oxygen green line with the green line of the aurora was finally established by McLennan and McLeod in 1927. It would appear that to account for all the features of the spectrum of the polar aurora that are known and understood, a 20-volt excitation of molecular nitrogen and of molecular oxygen would suffice, if applied occasionally and at irregular intervals.

The ever-present green light from the night sky may, like this aurora, be due to electrons emitted by the sun, or may be due to electrons from some other source; but it is more likely in this case that the atoms of oxygen are excited to emit the auroral green light by ultra-violet radiation of short wavelength which must be emitted by the sun, but which cannot penetrate the denser lower layers of the atmosphere. The author's recent investigation on the Zeeman effect of the green line is summarised and conclusions drawn. Recent observations by him and his associates appear to show definitely that there is a gradual increase in the intensity of the auroral light from the zenith of the clear night sky from sunset to about 1½ hours after midnight, after which it decreases until sunrise. He suggests that it will be interesting to see if any connection can be established between these variations and the daily variations known to occur in the state of ionisation of the upper atmosphere; and between height and thickness of the ozone layer and the intensity of the night sky radiation.

NOTES ON APERIODIC AMPLIFICATION AND APPLICATION TO THE STUDY OF ATMOSPHERICS.—A. Hund. (*See under* Properties of Circuits.)

PROPERTIES OF CIRCUITS.

THE EFFECT OF REGENERATION ON THE RECEIVED SIGNAL STRENGTH.—Van der Pol. (*Proc. Inst. Rad. Eng.*, August, 1928, V. 16, pp. 1045–1052.)

This paper gives a theory of the effect of regeneration, using the solution of a non-linear differential equation. It is shown that (*a*) as a first approximation, detection has no effect on the radio-frequency grid voltage developed under the influence of an incoming signal; (*b*) the amplification obtained through regeneration equals the two-thirds power of the ratio of " grid-space " to the amplitude obtained with zero regeneration; " grid-space " being the grid-voltage change necessary to bring the anode current from zero to its saturation value. It is apparent from (*b*) that much greater gain is obtained, through regeneration, with weak signals than with strong. The theory is verified by tests on a circuit operating at 500 cycles p.s., the applicability of the results being proved by the following theorem: " if a model is made of a H.F. system consisting of linear inductances and capacities and non-linear resistances (*e.g.* triodes) and if the values of all the inductances (self and mutual) and capacities in the model are made n times these values in the original H.F. system, but if the resistances (linear and non-linear) in the model are made equal to those in the original circuit, then the currents and potentials occurring in this model will be exactly equal in magnitude to those in the original H.F. system, but—considered as a function of the time—they will vary n times more slowly."

Parallel Resonance and Anti-Resonance.—W. J. Seeley. (*Journ. Am.I.E.E.*, September, 1928, V. 47, pp. 662–665.)

By parallel resonance is meant that condition existing among the elements of a parallel circuit which makes the resulting reactance or susceptance equal to zero; by anti-resonance, the condition of maximum impedance. The paper investigates the relations between the two conditions, which for a series circuit are identical but for a parallel circuit only under certain conditions. It is concluded that at radio frequencies, for resistances below 100 ohms, the two conditions are identical when resistance or capacity are the variables, and practically identical when inductance is the variable.

At low frequencies, the conditions are not identical except when capacity is the variable. The larger the ratio of L to C, the nearer they approach identity. At radio frequencies, the values of the impedances are nearly alike for ω, L or C as variables, but at lower frequencies they are quite different.

Effect of the Antenna in Tuning Radio Receivers and Methods of Compensating for It.—Sylvan Harris. (*Proc. Inst. Rad. Eng.*, August, 1928, V. 16, pp. 1079–1088.)

The reflected effect of the primary circuit of a tuned transformer, or of the aerial circuit of a receiver, upon the secondary coupled to it, is discussed. Equations are given for determining the apparent change of inductance in the secondary, and methods of compensating for these changes. The whole question is of importance in connection with gang control.

An Experimental Investigation of Forced Vibrations.—L. W. Blau. (*Journ. Frank. Inst.*, September, 1928, V. 206, pp. 355–378.)

The solution of the equation $y'' + 2Ry' + n^2y = E \cos pt$ is written in a new form which clearly exhibits important facts regarding this type of motion which have been overlooked owing to the form of the usual solution. Thus Barton and Browning's statement " While the free vibration is dying away, the resultant motion grows from nothing to the fixed amplitude and phase of the forced vibration " is shown to be true only for the special case when $n^2 - p^2 = R^2$. Again, Rayleigh stated, " During the coexistence of the two vibrations in the earlier part of the motion, the curious phenomenon of beats may occur, in case the two periods differ but slightly." The writer shows that, on the contrary, beats occur in every case, whether the difference between the frequencies be large or small (except in the one special case mentioned above); beats occur even at resonance in a damped system. The first beat maximum is always the greatest, and the first relative minimum occurring after the beginning is always the smallest minimum. In the experimental verification of the theory, the upper extremity of a simple pendulum was moved in S.H.M. and photographic records (shown in the article) were obtained of the motion of the bob. Different degrees of damping were used, ranging from very small to critical. The results are in excellent agreement with the theory.

The Tuned-grid, Tuned-plate, Self-oscillating Vacuum-tube Circuit.—J. W. Wright. (*Proc. Inst. Rad. Eng.*, August, 1928, V. 16, pp. 1113–1117.)

Certain discrepancies in published reports on this circuit (*cf.* Dow, *ibid.*, May, 1927) are pointed out and it is shown that the frequency of oscillation is given by the real terms, and the necessary conditions for these oscillations to start by the imaginary terms, of the general equation. The report in question neglected the effect of the feed-back current upon the total plate current. (*Cf. also* September Abstracts, G. H. d'Ailly.)

The Stability of a Valve Amplifier with Tuned Circuits and Internal Reaction.—R. T. Beatty. (*Proc. Phys. Soc.*, 15th August, 1928, V. 40, pp. 261–268.)

Algebraic and graphical methods for determining the conditions of stability for a tuned multi-valve amplifier are given.

Notes on Aperiodic Amplification and Application to the Study of Atmospherics.—A. Hund. (*Proc. Inst. Rad. Eng.*, August, 1928, V. 16, pp. 1077–1078.)

That a certain type of amplifier produces harmonic output currents for harmonic voltages of the same frequency is by no means proof that the system would give correct repeater action in all cases, as for instance when aperiodic discharges, study of atmospherics and the like are to be investigated with respect to their shape. The output current can, however, be interpreted in terms of the coupling. For true aperiodic amplification, the time constants have to be chosen such that the system gives true repeater action. An aperiodic amplifier using space-charge valves is shown.

Chains of Resonant Circuits.—E. Mallett. (*Journ. I.E.E.*, September, 1928, V. 66, pp. 968–974.)

A chain of resonant circuits coupled by mutual inductance is reduced to the more usual type of filter circuit or chain of T-links. A solution is obtained for the currents flowing, and this is applied to the chain of resonant circuits and to the case of asymmetrical T-links. A graphical construction of the solution is worked out. An appendix gives an example.

Zur Theorie der Siebketten (The Theory of Filter Chains).—Winter-Günther. (*Zeitschr. f. Hochf. Tech.*, August, 1928, V. 32, pp. 41–46.)

The method of treatment first used by Riegger, considering the filters as coupled oscillating circuits, cannot readily be applied to obtain the natural frequencies except in certain limited cases. The author shows how the use of the system of Normal Co-ordinates (brought into favour by Rayleigh and Routh) simplifies and extends the application of the method.

The Cause and Prevention of Hum in Receiving Tubes Employing Alternating Current Direct on the Filament.—W. J. Kimmel. (*Proc. Inst. Rad. Eng.*, August, 1928, V. 16, pp. 1089–1106.)

Conclusions are as follows: (*a*) The hum component due to temperature variation cannot be neutralised by the other factors since it lags by very nearly 90 deg. behind the power supply. This component, however, can be made so small as to be negligible. Oxide filaments of ordinary size are satisfactory. (*b*) With the use of straight filaments, the lowest hum is obtained by so choosing the filament characteristics that the hum components due to voltage drop and magnetic field neutralise each other. (*c*) The use of V-shaped filaments enables a very low minimum of hum to be obtained. (*d*) The effect of the A.C. drop along the filament is to place a sinusoidal potential on the grid; consequently, the hum produced by an A.C. valve increases with the amplification factor.

The Resonance Curves of Coupled Circuits.—E. Mallett. (*E.W. & W.E.*, August, 1928, V. 5, pp. 437–442.)

Inter-electrode Capacities and Resistance Amplification.—L. Hartshorn. (*E.W. & W.E.*, August, 1928, V. 5, pp. 419–430.)

The Harmful Effects of Inter-electrode Capacity.—v. Ardenne and Stoff. (*E.W. & W.E.*, September, 1928, V. 5, pp. 509–513.)

Effect of Anode-grid Capacity in Detectors and L.F. Amplifiers.—W. B. Medlam. (*E.W. & W.E.*, October, 1928, V. 5, pp. 545–555.)

Characteristics of Output Transformers.—J. M. Thomson. (*Proc. Inst. Rad. Eng.*, August, 1928, V. 16, pp. 1053–1064.)

The paper deals with the operating characteristics of the Output Transformer, which are developed in terms of the known constants of loud speaker, valve and transformer. The general formula for the loud speaker current is developed, and the effect of varying the transformer constants shown. The turn ratio of the transformer for maximum speaker current is considered in relation to the commonly used impedance ratio formula (I_2 maximum when turn ratio squared equals $\sqrt{\frac{R_2^2 + \omega^2 L^2}{R_1^2}}$). The limitation of this formula is pointed out and limits set for its general use. The general form of the current frequency characteristic for exponential horns and electro-dynamic cone speakers is then obtained, and a general method for matching the speaker to the output valve is given. Curves are given checking the mathematical results with experimental. The effect of the turn ratio on the form of the current frequency characteristic is shown and a method of using the turn ratio to match the speaker to the output valve is given. A perfect transformer is compared with a good commercial transformer, and the general effect of the leakage inductance and the self-capacity of the transformer is shown.

TRANSMISSION.

Ultrakurze Elektrische Wellen (Ultra-short electric waves).—A. Esau. (*Elektrot. u. Masch: bau, Radio Supp.*, No. 8, 1928, pp. 78–79.)

The writer places 80 cm. as about the present limit of shortness of waves of practical use for communication. Waves about 3 m. are extremely advantageous, as they can be produced efficiently and reflected by parabolic reflectors: the power required for covering a given distance is reduced to 1/12 by such reflectors, or to 1/150 by the addition of similar reflectors at the receiving end. Former difficulties in telephony have been overcome, and quality is now as good as in broadcast transmission. Receiving difficulties have been solved by the use of the reaction-audion with supersonic regenerative frequency (about 20,000 p.s.) incorporated in a 4-valve receiver giving double L.F. amplification. The choice of the type of valve is very important.

Recent range tests have shown extraordinarily good results: duplex telephony (loud speaker) over 20 km. was carried out on 1/60 W.; over 130 km. on 10 W. (without reflectors). Of special importance was the freedom from atmospherics, which had been troublesome on 15 m. even with a far less sensitive receiver. Moreover, signals were not disturbed by fog, rain, snow, or the change from day to night.

Measurement by Lecher wire has been replaced by the use of a special wavemeter here described. This has also been successfully used for measurements of damping.

The paper concludes by references to the promising medical application of these waves and to their use in increasing the sensitivity of measuring processes.

Theorie der Erzeugung von sehr Kurzen Elektromagnetischen wellen Mittels Elektronenröhren (Theory of valve-production of ultra-short E.M. Waves).—J. Sahánek. (*Phys. Zeitschr.*, 15th September, 1928, pp. 640–654.)

The first part of this paper was published in the same journal in 1925. The present part derives mathematically a common foundation for the several different methods for obtaining ultra-short waves (Barkhausen-Kurz, Gill-Morrell, Zácek), by considering the energy-changes in the diode with plane electrodes when an electron-stream, alternating in time with the external periodic E.M.F., proceeds from the cathode. The conditions under which the diode behaves as a positive resistance, and as a negative, are distinguished. The application of deductions from the diode to the production of waves as obtained by the before-mentioned workers is justified. Experimental results are given verifying the theoretical conclusions.

EIN RÖHRENOSZILLATOR FÜR SEHR KURZE UNGEDÄMPFTE WELLEN (A valve oscillator for very short undamped waves).—H. E. Hollmann. (*Ann. d. Physik*, 16th Aug., 1928, V. 86, pp. 1062–1070.)

The oscillator described and illustrated allows, by tuning of the external oscillatory system and a corresponding increase of working voltage, the wavelength to be decreased steadily down to 36 cm. Other waves, about an octave lower (down to 13.2 cm.) are also in evidence: these can be strengthened by tuning the grid lead. *Cf.* previous work, October Abstracts.

DIE ERZEUGUNG SEHR KURZE ELEKTRISCHER WELLEN MIT WECHSELSPANNUNG . . . (The Productions of very short waves with A.C. Voltage . . .).—W. Wechsung. (*Zeitschr. f. Hochf. Tech.*, August, 1928, V. 32, pp. 58–65.)

Final part of the paper mentioned in the October Abstracts. Among the conclusions arrived at are: Wavelengths depend not only on the applied voltage, but on the value of condenser: the Gill-Morrell equation $\lambda^2.E_g = \text{const.}$ is modified by the statement that $\lambda^2.E_g$ is dependent on valve dimensions and is equal to the square of the anode diameter multiplied by a constant, if valve dimensions and voltage are kept within certain limits.

GENERAL CONSIDERATIONS OF THE DIRECTIVITY OF BEAM SYSTEMS.—R. M. Wilmotte. (*Journ. I.E.E.*, September, 1928, V. 66, pp. 955–961.)

The author points out the ambiguity which arises from the use of the word "directivity" to cover two distinct quantities for which he introduces the terms "directive efficiency" and "sharpness of directivity." He then considers the general conditions for obtaining good sharpness of directivity in a beam system, and shows that a parabolic system is not, for given overall dimensions, the best arrangement for this. A method is described for obtaining maximum sharpness of directivity at any angle to the vertical, using an inclined antenna system and reflector. In considering the question of excitation, it is suggested that antennæ not directly connected to the source may be used. A possible improvement on the Franklin antenna is also described.

A THEORETICAL INVESTIGATION OF THE PHASE RELATIONS IN BEAM SYSTEMS.—Wilmotte and McPetrie. (*Journ. I.E.E.*, September, 1928, V. 66, pp. 949–954.)

To simplify problems connected with antenna systems and in particular beam systems, it is desirable to express the total field at any point in space in the form of a radiation field. In order to take account of the apparent change in type of field as the distance from the antenna increases, the equation for such a field must contain two variable factors depending on the distance, one governing the phase and the other the amplitude of the total field. The paper gives the calculations and curves for these factors. The best position for a reflector is considered and found to be not necessarily at a quarter wavelength behind the transmitter. The method of calculating from the curves the required positions of antennæ in a system for any given purpose is shown and specific cases are considered. The experimental results of Tatarinoff are compared with the theory.

THE NATURE OF THE FIELD IN THE NEIGHBOURHOOD OF AN ANTENNA.—R. M. Wilmotte. (*Journ. I.E.E.*, September, 1926, V. 66, pp. 961–967.)

The problem dealt with is the calculation of the effective E.M.F. induced in a receiving antenna from the field of a neighbouring transmitting antenna. It is treated with particular regard to the need for the evolution of a measure of the amount of disturbance caused by a transmitting station, and at the end of the paper the author suggests that a satisfactory though not perfect criterion of the interfering properties of such a station would be one dependent on the current and potential spectrum at the foot of its antenna.

POLAR DIAGRAMS DUE TO PLANE AERIAL REFLECTOR SYSTEMS.—T. Walmsley. (*E.W. & W.E.*, October, 1928, V. 5, pp. 575–577.)

ZUSAMMENGESETZTE RAHMENANTENNEN (Combined Frame Aerials).—Turlyghin and Ponomareff. (*Zeitschr. f. Tech. Phys.*, September, 1928, pp. 357–364.)

The equations and polar diagrams for various combinations of frame aerials are derived mathematically and confirmed by experiment.

RECEPTION.

BAU UND BETRIEB EINES KURZWELLENEMPFÄNGERS MIT EINER N.F.-DREIFÄCHRÖHRE (Construction and Use of a Short-wave Receiver with One L.F. Triple Valve).—M. v. Ardenne. (*Rad. f. Alle*, September, 1928, pp. 385–395.)

A one-valve receiver (Audion and L.F. amplification) for wavelengths of a range of about 12 to 80 metres. A list of some 60 commercial short-wave stations coming within this range is given, with call signs and wavelengths.

ACOUSTIC WAVE FILTERS AND AUDIO-FREQUENCY SELECTIVITY.—R. B. Bourne. (*Q.S.T.*, August, 1928, V. 12, pp. 23–29.)

Theoretical and practical description of an acoustic filter made up of a series of "bottle" resonators constructed from pieces of $1\frac{3}{16}$in. diameter brass tubing closed at one end and each connected to the main delivery tube by $\frac{3}{8}$in. diameter tubing, which is continued (on the other side of this delivery tube) to an open end. The combination forms a band pass filter which can be converted to a low pass filter by closing these open ends. The advantages, particularly for good autodyne reception, in place of the L.F. electric filter, are described, with particular reference to telegraphy in the crowded short-wave transmission bands prescribed for the U.S.A. amateur from 1st January, 1929.

Two-range Four.—F. H. Haynes. (*Wireless World*, 12th September, 1928, V. 23, pp. 311–316.)

An efficient long- and short-wave receiver without interchanging coils.

The Final or Power Stage of Amplifiers.—M. v. Ardenne. (*E.W. & W.E.*, October, 1928, V. 5, pp. 556–564.)

A New Idea for a Detector Valve (Posthumous). (*E.W. & W.E.*, September, 1928, V. 5, p. 515.)

A New Receiver: The Design of a Screened Grid and Pentode Three.—N. W. McLachlan. (*Wireless World*, 12th September, 1928, V. 23, pp. 302–305.)

Theoretical description of the new "Megavox Three," constructional details of which follow in the next week's issue.

VALVES AND THERMIONICS.

La Détection par Lampe (Detection by Valve).—P. David. (*L'Onde Élec.*, August, 1928, pp. 313–361.)

The writer introduces his long paper by saying that the phenomena of detection are by now familiar so far as the static régime is concerned, though even here there are no precise formulæ giving, for each type of valve, the efficiency of detection; while when the régime is no longer static, where the time-constants of the organs interposed in the circuit are no longer negligible, little is known of what happens, and various authors disagree as to the magnitude of the effects introduced. He sets himself to clear up these points by calculation and experiment. The first nine pages are given to the general method of treatment of static and dynamic characteristics; the algebraic solutions are supplemented by the corresponding graphic representation.

The next eight pages examine, so far as detection is concerned, the various ways of representing the valve characteristic: (1) as parabolic (shown to be applicable only for some tenths of a volt—grid, or a few volts—plate); (2) as exponential (Colebrook)—shown to begin to fail for signals passing $+ 0.1\ V$; as half rectilinear, half parabolic (Kuhlmann)—fairly good for signals up to 1 or 2 V; and as composed of two straight lines, which for strong signals is better than the other hypotheses. The next twenty pages give the application of the preceding work to actual circuits: (A) anode detection; (B) grid detection (shunted condenser) first for unmodulated, then for modulated C.W.; and (C) superheterodyne detection. In B it is shown, among other things, that detection by shunted condenser (grid) method gives a deplorable efficiency for supersonic frequencies, *e.g.*, 50,000. In C this is reconciled with the fact that super-heterodyne receivers function well, by the conclusion that detection in these, contrary to general belief and in spite of the presence of a shunted condenser, is not by grid but by plate. The final seven pages give a description of the apparatus used for the measurements on detection in the static condition and on detection of modulated waves. The paper ends with a bibliography of thirty-seven items and is followed by a short postscriptum.

Zur Theorie der Raumladegitterrohren (The Theory of the Space Charge Grid Valve) Part I.—F. Below. (*Zeitschr. Fernmeldetech.*, 29th August, 1928, pp. 113–118.)

The Application of Alignment Charts to Valve Characteristics.—M. Reed. (*E.W. & W.E.*, October, 1928, V. 5, pp. 571–574.)

The Action of Strong Electric Fields on the Current from a Thermionic Cathode.—de Bruyne. (*Proc. Roy. Soc.*, September, 1928, V. 120A, pp. 423–437.)

Results obtained with fields up to 10^6 volts/cm. showed that the Schottky relation, and therefore the Maxwellian velocity distribution, here holds good. It was known that electrons having energies greater than 4.53 V (the work function of tungsten) have a Maxwellian velocity distribution. These new results extend the limit down to about 4.2 volts, so that it may be said that not only do those electrons which are able to escape by their own energy in the absence of an external field have a Maxwellian velocity distribution, but also electrons of ⅓ volt less energy than that corresponding to the work function. The writer points out that his results with filaments of different diameter show conclusively that it is the field at the surface of the cathode which is the decisive factor in controlling the rise in saturation current (*cf.* del Rosario, Bartol Foundation, August Abstracts, p. 469, work on *cold* emission from wires). The value $E = 4.8_4 \times 10^{-10}$ E.S.U. is obtained for the electronic charge, from results on three filaments.

DIRECTIONAL WIRELESS.

Le Chemin du Rayon Électromagnétique (The Path of the electromagnetic Ray).—de la Forge. (*Q.S.T. Fran.*, September, 1928, pp. 9–13.)

The first part of a long analysis of Special Report No. 5 of the Radio Research Board: "A Study of Radio Direction-Finding."

L'Excitation d'une Antenne en Fonction de la Direction du Champ Électromagnétique (The Excitation of an Aerial as a Function of the Direction of the E.M. field).—G. Hack. (*Q.S.T. Fran.*, September, 1928, pp. 22–26.)

The author points out that with short waves the phase-differences produced by the waves striking different parts of the receiving aerial give a directional effect similar to that of a transmitting aerial oscillating on a harmonic. The article (which is to be continued) proceeds to analyse the effect.

MEASUREMENTS AND STANDARDS.

Sulla Misura della Lunghezza d'Onda (Wavelength Measurement).—Pession and Gorio. (*Electrotecnica*, 5th July, 1928, V. 15, pp. 524–530.)

A description of the methods of precise measurement employed by the Italian Royal Inst. Research (Communications) for wavelengths from 100 to 30,000 metres. Abraham multi-vibrators are employed, in combination with electrically maintained tuning forks based on Eccles' circuit.

A New Type of Standard Frequency Piezo-Electric Oscillator.—Wheeler and Bower. (*Proc. Inst. Rad. Eng.*, August, 1928, V. 16, pp. 1035–1044.)

Tests on the ordinary piezo-electric oscillators lead the author to conclude that the comparatively close coupling needed, and the effect of the associated valve constants, result in an unavoidable error of nearly 0.001 per cent. under ordinary laboratory conditions, or nearly 0.0001 per cent. under the very best conditions (*i.e.*, at the time of a calibration and with better than ordinary temperature control). The new type, developed at the U.S. Naval Laboratory, has given preliminary results indicating that its average frequency has not varied by as much as one part in a million (over a period of time not specified) and that in all probability the variations are much smaller than that. The chief cause of this constancy is the manner in which the energy necessary to sustain the oscillations of the quartz bar is returned to it, namely, by an acoustic feed-back: the amplified piezo-electric voltage operating a loud speaker element which in turn actuates a tunable air-column and resonator, from which the bar receives its sustaining energy. Extremely loose coupling is thus secured. The paper also describes auxiliary apparatus to permit the continuous operation of the oscillator over very long periods of time, and to measure the frequency with the highest possible precision.

Magnetostriction Oscillators.—G. W. Pierce. (*Nature*, 8th September, 1928, V. 122, p. 380.)

Résumé of a paper in the April number of the *Proceedings of the American Academy of Arts and Sciences.* The writer describes a method of applying the magnetostriction of a rod to produce, and control the frequencies of, electrical and mechanical oscillations ranging from a few hundred to several hundred thousand cycles per sec. These new oscillators seem likely to take the place of piezo-electric oscillators for frequencies below 25,000 p.s., and to compete with them at higher frequencies, though above 300,000 p.s. the present form of magnetostriction oscillator does not work well.

Über eine Neukonstruktion der Linear Thermosäule (A new construction of the Linear Thermopile).—H. Keefer. (*Phys. Zeitschr.*, 15th September, 1928, pp. 681–683.)

The author claims superiority in working and in ease of construction for this new design over the previous versions of Voege and Moll. Thin hair-filaments of copper and constantin or iron and constantin are used.

Frequency Stability of Piezo-electric Quartz.—P. Vecchiacci. (*L'Elettrotech.*, 15th June, 1928, V. 15, pp. 462–468.)

The method of investigation was designed for a high order of accuracy. Results indicated a constancy of control varying from 1/20,000 to 1/100,000, according to the order of frequency. Coefficients are obtained for variation due to change of temperature.

Notes on Quartz Plates, Air Gap Effect, and Audio-frequency Generation.—A. Hund. (*Proc. Inst. Rad. Eng.*, August, 1928, V. 16, pp. 1072–1076.)

Experiments on the frequency of piezo-electric elements are described, with special reference to the effect due to supersonic sound waves generated in the air-gap of the holder and due to its capacity. It is shown that a mechanical load on the crystal increases its thickness-frequency and that an air-gap has the same effect. The velocity of the supersonic waves is about the same as for ordinary sound waves. The value found is 338.68 metres p.s. at 24.5 deg. C. An appropriate air-gap gives even more H.F. output than a mechanically loaded crystal, and procures a steady frequency operation. Two sputtered elements can produce a beat frequency correct within a few parts in 100,000. A method is shown for obtaining a L.F. standard by harmonic division of a H.F. due to a piezo-electric element, sputtered metal electrodes being used. These sputtered electrodes seem most promising for L.F. work, while settings with an air-gap are of value for H.F.

A Quartz Fibre Electrometer.—D. R. Barber. (*Phil. Mag.*, September, 1928, V. 6, pp. 458–465.)

A double-plate instrument employing a single suspended quartz fibre as the moving system. The quartz is rendered conducting by cathode disintegration of silver. The high sensitivity obtained at comparatively low plate potentials, and the stability of the fibre over extended periods of observation, are advantages claimed.

Nagra Teoretiska Synpunkter pa Smärre Mottagnungsantenner (Some theoretical points on small receiving aerials).—E. T. Glas. (*Teknisk Tidskrift, Sweden*, 1st September, 1928, V. 58, pp. 150–155.)

Results are expressed in curves. In one of these figures the ordinates represent the ratio $\frac{h_{eff}}{h}$ while the abscissa represent $\frac{l}{h}$ (ratio of horizontal part of aerial to height) and the three curves correspond to $\frac{h}{\lambda} = 0$, $\frac{1}{60}$ and $\frac{1}{30}$. All three show how the effective height ratio varies from about one-half to nearly unity. A second figure shows how the eff. height ratio varies with an increase of the ratio vertical height to wavelength. Here the four curves correspond to $\frac{l}{h} = 0, 1, 2$ and 3. Other curves deal with the aerial with series inductance or capacity.

Ein Instrument zur Messung von Induktivitäten und Kapazitäten (An instrument for the measurement of inductance and capacity).—Täuber-Gretler. (*Phys. Berichte*, 15th August, 1928, pp. 1509–1510.)

An induction dynamometer with associated apparatus enabling inductances, self and mutual, and capacities to be measured with an accuracy of about 1 per cent. Wide limits for the magnitudes are allowable, and the scale is marked directly in microfarads and henries.

A Note on Methods of Rapidly Adjusting a Radio-frequency Oscillator in Small Steps of Frequency.—J. K. Clapp. (*J. Opt. Soc. Am.*, August, 1928, V. 17, pp. 132–137.)

Simple and rapid aural methods are described. By the use of the *n*th harmonic of the H.F. oscillator the steps of frequency can be made $1/n$ times a convenient fixed L.F., such as that of a tuning fork. By slight elaboration of the equipment, the adjustments may be made with an accuracy of $1/n$ cycles per second.

A Non-inductive Potential Divider of High Precision. (*Journ. Sci. Inst.*, August, 1928, V. 5, pp. 257–258.)

An instrument on the Thomson-Varley principle; each graduation of the circular slide wire represents one part in a million of the total resistance. The four resistance dials are specially connected so that each is balanced.

Théorie des Appareils de Mesure Électromagnétiques et Description d'un Nouvel Appareil à Deux Fers Répulsifs (Theory of electromagnetic measuring instruments, and description of a new instrument with two repelling iron elements).—S. S. Held. (*Rev. Gén. de l'Élec.*, 1st September, 1928, V. 24, pp. 307–317.)

The special (triangular) form of the magnetising coil and the use of two repelling iron elements gives a maximum couple with a minimum of ampere-turns, and a uniform scale starting at 1-10th of the maximum graduation.

Radiation and Induction.—Ramsey and Dreisback. (*Proc. Inst. Rad. Eng.*, August, 1928, V. 16, pp. 1118–1132.)

The formulæ for radiation from an aerial and from a coil have been worked out by Dellinger, using a vector potential. The present paper derives these formulæ by more elementary methods. Radiation theory has been experimentally verified with considerable accuracy when the distances have been hundreds of miles, involving an attenuation factor the uncertainty of which explains any discrepancies. The writers state that there seems to have been no attempt made to verify the formula when the distance is small—one wavelength or less. This paper verifies the laws of radiation and induction experimentally, close to a loop aerial. Discrepancies are explained by reflection or re-radiation from certain trees and an iron fence.

On the Mounting of Wires in String-electrometers.—W. Clarkson. (*Journ. Sci. Inst.*, September, 1928, V. 5, pp. 298–299.)

In some recent work with a string electrometer, these modifications of the usual technique in mounting the wires were made with, it is believed, an increase in speed and in reliability.

A Long-period Galvanometer.—D. C. Gall. (*Journ. Sci. Inst.*, September, 1928, V. 5, pp. 280–281.)

By using the magnetic properties of a galvanometer coil to increase its periodic time instead of allowing it to decrease that time, as is usually the case, the writer has increased the deflection per microamp. from 350 to 1,300 mm., since the sensitivity rises almost as the square of the periodic time. The zero-keeping qualities, however, are not good, and the scale law is very uneven, so that the usefulness of the arrangement would be limited to special cases.

The Valve Voltmeter for the Measurement, Without Loss, of High Tensions.—L. Weisglass. (*E.T.Z.*, 24th May, 1928, V. 49 p. 796.)

Basic Measurements of the Effective Resistance of Condensers at Radio-frequencies.—D. W. Dye. (*Proc. Phys. Soc.*, 15th August, 1928, V. 40, pp. 285–295.)

The paper includes a description of a special air condenser, so constructed that a change in its capacity can be made without change in the losses, and of a method of using such a condenser to measure the losses in a variable air condenser.

Contact Potential in the Dolezalek Electrometer Connected Idiostatically.—L. F. Richardson. (*Proc. Phys. Soc.*, 15th August, 1928, V. 40, pp. 234–239.)

The importance of reversing the voltage and taking the mean of the two deflections is pointed out. In the discussion, various ways of eliminating or reducing the contact potential effect are mentioned.

The Dielectric Constant of Air at Radio-frequencies.—Bryan and Sanders. (*Phys. Review*, August, 1928, V. 32, pp. 302–310.)

By the radio-frequency method described, the value found for K for dry air free from CO_2 and at standard temperature and pressure is 1.0005893. Preliminary measurements made with a large D.C. voltage superimposed on the H.F. voltage across the condenser indicate no change in the value for air, hydrogen or ammonia. There is some indication that a discharge through the gas decreases its dielectric constant, but the effect is probably spurious.

A Simple Gold Leaf Electrometer for High-frequency Measurements. — Satyendranath Ray. (*Proc. Phys. Soc.*, 15th August, 1928, V. 40, pp. 307–311.)

The entire freedom from time-lag, the practically negligible power consumption, and the much lower degree of coupling to the exciting circuit, constitute very appreciable advantages over the thermo-element and micro-galvanometer usually employed in resonance-circuit measurements.

Druckmessung in Vakuumglühlampen Mittels Aussenelektrode (Vacuum measurement in incandescent lamps by the use of an external electrode).—Alterthrum and Ewest. (*E.T.Z.*, 30th August, 1928, p. 1303: summarised.)

The Measurement of Small Variable Capacities at Radio-frequencies.—W. H. F. Griffiths. (*E.W. & W.E.*, August, 1928, V. 5, pp. 452–459.)

A Graphical Construction for Resistance Amplifiers.—W. A. Barclay. (*E.W. & W.E.*, September, 1928, V. 5, pp. 499–502.)

Loop Permeability in Iron, and the Optimum Air-gap in an Iron Choke with D.C. Excitation.—A. A. Symonds. (*E.W. & W.E.*, September, 1928, V. 5, pp. 485–490.)

Some Output Power Measurements on a Moving Coil Drive Loud Speaker.—Clark and Bligh. (*E.W. & W.E.*, September, 1928, V. 5, pp. 491–498.)

A Direct-reading Valve Tester.—M. G. Scroggie. (*E.W. & W.E.*, September, 1928, V. 5, pp. 480–484.)

The Design of Non-contact Thermo-junction Ammeters.—Colebrook and Wilmotte. (*E.W. & W.E.*, October, 1928, V. 5, pp. 538–544.)

On the Application of Condensers to the Measurement of Large Radio-frequency Currents.—P. R. Coursey. (*E.W. & W.E.*, October, 1928, V. 5, pp. 565–571.)

SUBSIDIARY APPARATUS AND MATERIALS.

Eine Neue Methode Unmittelbarer Steuerung der Luft Durch Elektrische Schwingungen (A new method of direct control of air by electric oscillations).—Brenzinger and Dessauer. (*Phys. Zeitschr.*, September 15th, 1928, pp. 654–655.)

A method which avoids the usual mechanical go-between (membrane, vibrating string or metal band) and consequent distortion, by the direct control of ionised air by the varying electric field. The ionisation is produced by a glow-discharge. The process is reversible, so that it can be applied to a microphone transmitter or to a loud speaker. Excellent quality is obtained, especially in the articulation of consonants. Practical difficulties are: the amount of power required (at present 20-40 Watts), and—more important—a background-noise even when a quiet glow-discharge is attained.

Die Erzeugung sehr hoher Gleichspannung (The production of very high D.C. voltage).—E. Marx. (*Elektrot. Zeitschr.*, No. 6, 1928, V. 49, pp. 199–201.)

From a transformer A.C. voltage of 100 kV, the arrangement described gives a D.C. voltage of 1,000 kV, which can be employed for X-ray production, for cathode-ray oscillographs, etc. The method depends on the charging of condensers in parallel and their discharge in series, spark-gaps and hot-cathode rectifiers being employed.

Cathode-ray Oscillographs and their Uses.—E. S. Lee. (*Gen. Elec. Rev.*, August, 1928, V. 31, pp. 404–412.)

Deals with the general principles: fundamental types: characteristics: detailed description of the G.E.C. portable instrument, including frequency range, sensitivity and timing arrangements: and finally, applications and uses, illustrated by specimen oscillograms taken on periodic and transient phenomena.

Characteristics of Photo-electric Tubes.—Koller and Breeding. (*G.E. Review*, September, 1928, V. 31, pp. 476–479.)

The article includes a number of characteristic curves of Light, Current, Sensitivity, and Gas Pressure, relating to various types of cell, some vacuum and some gas-filled.

Der Harmonische Analysator, ein neues Planimeter (The harmonic Analysator, a new planimeter).—K. Trott. (*Bull. d. l'Assoc. Suisse d. Élec.*, 22nd August, 1928, p. 534.)

This new planimeter, Mader-Ott system, gives the magnitudes and phase of the fundamental and harmonic oscillations of periodic curves.

Some New Methods of Linking Mechanical and Electrical Vibrations.—Eccles and Leyshon. (*Proc. Phys. Soc.*, 15th August, 1928, V. 40, p.p. 229–233.)

A full version of the paper, a notice of which was referred to in September Abstracts.

The Grid-glow-valve Relay.—D. D. Knowles. (*E.T.Z.*, 13th September, 1928, p. 1371).

Résumé from the *Electric Journal*, V. 26, p. 176. The writer points out that ordinary mechanical relays give a magnification of the order of 500, increased in the case of the more sensitive relays to 10,000. The Grid-Glow Relay will reach 100,000,000. Details of manner of employment are given: among applications, the use with photo-electric or selenium cells is mentioned. A general objection is the 400 V needed: the writer hopes that this will be reduced to about 100.

Note sur un Montage de Deux Lampes Amplificatrices en Pont Equilibré (Note on a Balanced Bridge Valve Circuit.)—H. Copin. (*L'Onde Élec.*, August, 1928, pp. 361–363.)

For radio-telegraphic recording, etc., where an electro-magnetic relay is used, it is often desirable to use an amplifier whose current keeps at zero during a "space." Suppression of the permanent current by negative grid bias is not always satisfactory. Differential relays are not always available. The arrangement described possesses all the advantages of these relays and involves no special apparatus. Two 3-electrode valves are opposed both for input and output, balancing being adjusted by filament control. If desired, a slight polarisation in the sense opposite to that of the marking current can be arranged.

The Jet-wave and its Applications.—J. Hartmann. (*Engineering*, 14th September, 1928, V. 126, pp. 345–348., and Die Konstruktive Durchbildung des Quecksilber-Wellenstrahl-Gleichrichters (The development of the Mercury-Jet-Wave-Rectifier).—*E.T.Z.*, 16th August, 1928, pp. 1224–1226.)

Two articles describing the work of Professor Hartmann in Copenhagen and his remarkable rectifier—a pendulum rectifier one form of which deals with some 400 A at 230 V and works without trouble for nine months on end. A jet of mercury flowing between the poles of a magnet carries the alternating current and is thus set into a kind of wave-motion which is used to connect the jet in turn with two fixed contacts. These, combined with a centre tapping of a transformer, lead to the production of a pulsating rectified current. The English paper describes other applications: as an interrupter for induction coils: as frequency-meter: and as oscillograph.

Die Verluste in Geschichteten Isolierstoffen (Losses in stratified insulating material).—W. Burstyn. (*E.T.Z.*, 30th August, 1928, pp. 1289–1291 and 1311–1314.)

These losses are attributed to glow-currents in the inferior dielectric (*e.g.*, shellac in the case of Micanite) and the author reckons approximately the variation of the loss-angle with the electrical strain. Loss-angle $= \tan^{-1} \frac{1}{2\pi}$ (energy lost in 1 period/charging energy).

Höchstspannungsisolatoren Hoher Lebensdauer aus Organischem Werkstoff (Extra high tension insulators of organic materials).—O. Scheller. (*Elektrot. Zeitschr.*, No. 8, 1928, V. 49, pp. 295–296.)

These materials are attractive because of their mechanical properties, but are liable to deterioration by corona, etc., which may lead to fracture, especially as the action usually coincides with the place where mechanical strain is taken. The author therefore suggests (and quotes results with) a special form of insulator in which the conductor is carried by a frill or ruffle separated from the point of mechanical strain.

Development of a System of Line Power for Radio.—G. B. Crouse. (*Proc. Inst. Rad. Eng.*, August, 1928, V. 16, pp. 1133–1148.)

Among interesting points in this paper (which begins by reviewing the gradual progress of mains supply arrangements from 1924 to to-day) may be mentioned two cheap and reliable voltage-control devices, one a temperature-variant resistance, the other purely magnetic; a table of the latest Tungar, Radiotron and Raytheon rectifiers; and a filter of the inductance-resistance type, which is a "blanket filter" having a high degree of suppression at all frequencies and a distinct anti-resonance point which may be designed to fall at one desired frequency.

Über Materialien mit Hoher Anfangspermeabilität (Materials of high initial permeability).—Yensen and Gumlich. (*E.N.T.*, August, 1928, V. 5, pp. 334–336.)

A discussion on a paper of this title (*E.N.T.*, February, 1928), dealing with the various new alloys, Permalloy, Conpernik, Hipernik, etc., some of which contain, in addition to iron and nickel, traces of silicon and manganese.

Magnetic Properties of Perminvar.—G. W. Elmen. (*Journ. Frank. Inst.*, September, 1928, V. 206, pp. 317–338.)

Perminvar is the name given to the group of iron-cobalt-nickel alloys which are characterised, when properly heat-treated, by constancy of permeability for a considerable range of the lower part of the magnetisation curve, by small hysteresis loss throughout the same range of flux densities, and by a very unusual hysteresis loop constricted at the origin for medium flux densities.

The Hall High-speed Recorder. (*Journ. Am.I.E.E.*, July, 1928, V. 47, pp. 516–519.)

Designed chiefly for studying effects which occur at the moment of a fault developing on a transmission line, this instrument is so constructed as to be portable, yet very sensitive owing to its optical system (photographically recording). It can be made quadruple for simultaneous records.

Oszillographische Untersuchungen an Gleichrichtern (Oscillographic Tests on Rectifiers).—G. Tenzer. (*Elektrot. u. Masch. bau, Radio Supplement*, No. 9, 1928, pp. 84–86.)

Oscillograms are given, showing the behaviour of various types of rectifier when charging accumulators or providing anode high tension.

Back-coupling in Eliminators.—W. I. G. Page. (*Wireless World*, 26th September, 1928, V. 23, pp. 381–384.)

The possibilities of a new neutralising scheme in L.F. amplifiers to overcome "motor-boating."

STATIONS, DESIGN AND OPERATION.

LA DIRECTION DES ONDES RADIOÉLECTRIQUES : IDÉES ET RÉALISATIONS RÉCENTES (The direction of radioelectric waves : recent ideas and results).—L. Bouthillon. (*Bull. d.l. Soc. Fran. d. Élec.*, September, 1928, V. 8, pp. 657–679.) and

LIAISONS RADIOTÉLÉPHONIQUES À GRANDE DISTANCE PAR ONDES COURTES PROJETÉES (Long distance radiotelephonic communication by short wave beam).—H. Chireix. (*Ibid.*, pp. 680–691.)

At the end of the first paper the writer gives results on the Ste. Assise—Buenos Ayres circuit, obtained during the past few months. The second paper deals with more specialised points : *e.g.*, simultaneous emissions from one transmitter ; secrecy ; suppression of "echo." The liaison Paris-Saïgon has just been successfully established.

A PROPOS DE LA MULTICOMMUNICATION PAR TRÈS COURTES ONDES ÉLECTRIQUES.—A. Turpain. (*Bull d.l. Soc. Fran. d. Élec.*, September, 1928, V. 8, pp. 774–775.)

The writer chastises a compatriot who slighted his early experiments (see October Abstracts) as merely "laboratory results" : he firsts points out that the resulting patent has quite recently been modified (by the substitution of a 3-electrode valve for the detector which the writer specified) by someone else who has thus taken out a new patent and sold it lucratively to the Americans ; and then quotes example after example of "laboratory results" which have stimulated and inspired industry.

GENERAL PHYSICAL ARTICLES.

THE THEORY OF FERROMAGNETISM.—W. Heisenberg. (*Nature*, 8th September, 1928, V. 122, p. 380.)

Résumé of a German article which is spoken of as "an important advance in magnetic theory." The new theory predicts two further conditions which must be satisfied for ferromagnetism to occur. One is that the space-lattice must be such that each atom has at least eight neighbours, and the other is that the total quantum number of the electrons responsible for the magnetism must be not less than three. (*Cf.* Honda, October Abstracts.)

DIE MAGNETOSTRIKTION (Magnetostriction).—A. Schulze. (*Zeitschr. f. Phys.*, 7th September, 1928, V. 50, pp. 448–505.)

The first long part of a systematic investigation of the phenomenon : its dependence on the purity of material, on thermal preparation, and on the constitution of alloys ; with a view to correlating this property with the magnetic and (if possible) with other physical properties of the material. Heterodyne methods used for the measurement of the dimensional changes are described in detail. The paper begins with a description of the work hitherto done on the subject, with many references, and points out its importance not only for the theory of the nature of magnetism but also for metallurgical purposes.

ÜBER DAS VERHALTEN VON WISMUTSCHICHTEN IN MAGNETFELD (The behaviour of Bismuth leaf in a magnetic field).—F. Gross. (*Zeitschr. f. Phys.*, 7th September, 1928, V. 50.)

Bismuth leaf (0.3 to 3μthick) shows resistance change in a magnetic field just as bismuth wire does. A thin leaf rotated in a field gives a resistance-change dependent on the angle with the lines of force. For a thick leaf no such dependence is found.

NEGATIVELY MODIFIED SCATTERING.—Saha, Kothari and Toshniwal ; and THE SCATTERING OF LIGHT BY FREE ELECTRONS ACCORDING TO DIRAC'S NEW RELATIVISTIC DYNAMICS.—Klein and Nishina. (*Nature*, 15th September, 1928, V. 122, pp. 398–399.)

The first paper points out that Raman and Krishnan's discoveries are a confirmation of Smekal's "negatively modified scattering" theory rather than of Einstein's deduction of negative or stimulated emission ; that the theory of modified scattering explains the phenomena of resonance spectra of vapours of sodium, potassium and the halogens, described by R. W. Wood ; and that the phenomen, though described as scattering, seems really to be intermediate between pure scattering (*e.g.*, by fog particles) and pure absorption. The phenomena should also be capable of extension to free electrons, and will thus probably afford an easy explanation of the origin of bright and broad bands in the spectra of Novæ and of winged lines in the solar spectrum. The second paper deals with the Compton scattering, and compares the writers' new formula with that of Dirac and Gordon ; pointing out incidentally the bearing which their calculations may have on the estimation of the wavelengths of the cosmic penetrating radiation.

A NEW RADIATION.—C. V. Raman. (*Indian Journ. of Phys.*, No. 3, 1928, V. 2, pp. 387–398.)

A survey of the work done on the dispersion of light during the past year at the author's Institute (*vide* various recent abstracts).

WAVELENGTH SHIFTS IN SCATTERED LIGHT.—R. W. Wood. (*Nature*, 8th September, 1928, V. 122, p. 349.)

A cabled message verifying and extending Raman's discoveries (*cf.* recent Abstracts). The writer says "Raman's discovery thus makes possible investigation remote infra-red regions hitherto little explored owing to experimental difficulties."

THE VOLTA EFFECT.—A. W. Porter. (*Electrician*, 14th September, 1928, V. 101, pp. 289–290.)

Extracts from Address to Section A, British Association. Recent developments place controversial subjects on new footing : Lord Kelvin's discovery : what happens at the zinc-liquid junction ? difficulties of the electronic theory.

CORPUSCULAR THEORY.—G. Forbes. (*Nature*, 8th September, 1928, V. 122, pp. 345–346.)

The writer recalls his paper to the British Association of 1878 on "Mutual Action of Vortex Atoms and Ultramundane Corpuscles" based on the theory of Le Sage and its development by Kelvin. Le Sage's theory was roughly that ultramundane corpuscles are flying through space in all directions with great velocity; that they collide with the atoms of mundane matter; and that in consequence they issue from the sun or a planet with less velocity than that with which they entered it; thus producing the effect known as gravitation. Kelvin suggested that the energy of translation lost by the corpuscles might be converted into vibrations, or vibrations and rotations; and formulated his vortex ring ideas of atom and corpuscle. J. J. Thomson was also attracted by the Le Sage theory.

Then came Aitken with his experiments on the rigidity of endless chains in rapid motion; it then appeared that the vortex filaments in Kelvin's corpuscle would behave in the same way, and that these corpuscles might form the basis of a corpuscular theory of light. The present writer's paper endowed the corpuscle with kinks or saw-teeth; and by these explained radiation, propagation and absorption of light. He revives this theory as forming a physical basis for quanta, for Einstein's photo-electric theory, for the heat of stars, and for Eddington's law of the mass luminosity of stars.

CONDENSIBLE GAS MODIFICATIONS FORMED UNDER THE INFLUENCE OF ELECTRODELESS DISCHARGES.—J. Taylor. (*Nature*, 8th September, 1928, V. 122, p. 347.)

Experiments on the electrodeless discharge in the common gases, using a 7-metre wave oscillator, lead the writer to regard the glass of the container as a complex electrolytic solution probably containing peroxides (until they are reduced by continued discharge with hydrogen) and certainly containing compounds of carbon which produce chemical reactions with the gas ions impinging against the glass surface.

EINE METHODE ZUR BESTIMMUNG DER KERR KONSTANTE SCHLECHT ISOLIERENDER STOFFE MIT HILFE ELEKTRISCHER WECHSELFELDER (A method of determining the Kerr Constant of badly insulating materials with the help of electric A.C. fields).—W. Ilberg. (*Phys. Zeitschr.*, 15th September, 1928, pp. 670–676.)

ON THE ULTRA-VIOLET RADIATIONS EMITTED BY POINT DISCHARGES.—J. Thomson. (*Phil. Mag.*, September, 1928, V. 6, pp. 526–546.)

Experiments to find further evidence as to the nature of these radiations and their relation to the discharge. J. Taylor has pointed out the possibility that they (or radiations of slightly longer wavelength) may be of first importance in determining the mechanism of the spark discharge. The present writer suggests, from his preliminary results, that the radiations are molecular in origin. Oxygen shows, under the conditions of the tests, a particular phenomenon of spontaneous ionisation which is explained by the suggestion that accompanies a gradual change from the O_3 molecule to the normal O_2.

NOTE ON THERMIONIC EMISSION.—Lewi Tonks. (*Phys. Review*, August., 1928, V. 32, pp. 284–286.)

Author's abstract: Electron emission experiments can throw light on the surface heat of charging only if the density of electrons in equilibrium with an emitting surface is the same whether evaporation occurs with constant surface charge or with surface charge equal (and opposite in sign) to evaporated charge. This equality is proved thermodynamically in the present note.

SCHWINGUNGEN PIEZOELEKTRISCHER QUARTZSTÄBE HERVORGERUFEN DURCH EIN UNGLEICHFÖRMIG VERTEILTES FELD (p.e. quartz rod oscillations produced by a non-uniformly distributed field).—S. J. Sokoloff. (*Zeitschr. f. Phys.*, 28th August, 1928, V. 50, pp. 385–395.)

Mandelstam and Papalexi in Leningrad have carried out experiments on the above subject, obtaining by these specially-shaped fields stronger excitation and stronger effects than have been obtained before. The writer investigates the condition mathematically and concludes that with this method of excitation, the oscillation amplitude is not (as v. Laue found for a uniform A.C. field) inversely proportional to the third power of the overtone, but to the first power.

VERSUCHE ÜBER ELEKTRONENBEUGUNG AM OPTISCHEN GITTER (Experiments on the diffraction of electrons at an optical grid).—E. Rupp. (*Naturwissensch.*, 17th August, 1928, p. 656.)

The writer claims the first successful result.

KATHODENZERSTÄUBUNGSPROBLEME (Cathode Sputtering).—Blechschmidt and v. Hippel. (*Ann. d. Physik*, 16th August, 1928, V. 86, pp. 1006–1024.)

Further development, theoretical and experimental, of the investigations by these workers published in 1926.

MISCELLANEOUS.

ELECTRICAL PROSPECTING.—J. J. Jakosky. (*Q.S.T.*, June, 1928, V. 12, pp. 9–18.)

A paper based on the work of the Radiore Company in prospecting by inductive methods. The "energizer" (with its frame aerial) can generate at will audio, high, or intermediate frequency currents. Two forms of D.F. receivers are illustrated, the more complex one being used in working with out-of-phase and distorted fields. This consists of a completely shielded ("compensated antenna pick-up") receiver and two coils rotatably mounted on a six-foot arm. The two identical coils impress their E.M.F.'s on separate valves whose outputs are opposed. The whole process of making a complete survey map is described.

RADIO ACOUSTIC POSITION FINDING IN HYDROGRAPHY.—J. H. Service. (*Journ. Am.I.E.E.* September, 1928, V. 47, pp. 670–674.)

For fixing the exact position of a survey ship, the U.S. Survey has developed a radio acoustic method, differing from the British method in that the information is obtained directly on the ship instead of being obtained on shore and transmitted thence to the ship. In the former method, the temporary shore-stations are entirely automatic, their radio signals being started by microphone-and-relay arrangements on the arrival of the explosion wave at the microphone. The paper includes a bibliography of 11 items.

KOMMISSION FÜR HOCHFREQUENZTECHNIK: Regulations for Electric Sound-apparatus such as Loud Speakers, Head-telephones, etc.—(*E.T.Z.*, 13th September, 1928, p. 1380, 1, 4, 5.)

Regulations of the Association of German Electrical Engineers as to insulation, etc.

BILDÜBERTRAGUNG UND FERNSEHEN (Picture Telegraphy and Television).—R. Hiecke. (*Elektrot. u. Masch. bau*, Radio Supplements, Nos. 7 and 9, 1928.)

Instalments (to be continued further) of a survey of the various progressive steps up to the present time, given in the form of a series of abstracts from patents and publications, roughly in chronological order.

ÜBER ELEKTRISCHE FELDER PHYSIOLOGISCHEN URSPRUNGS (Electrical fields of physiological origin).—W. O. Schumann. (*Zeitschr. f. Tech. Phys.*, September, 1928, pp. 315–321.)

The paper is illustrated by a number of curves from a string galvanometer actuated, through an amplifier, by the rapidly varying fields in the neighbourhood of a living being enclosed in a Faraday Cage (*cf.* von Ardenne, October Abstracts).

THE POSSIBLE APPLICATION OF HIGH-FREQUENCY POWER TO ELECTRIC TRACTION.—W. Cramp. (*Engineer*, 21st September, 1928, V. 146, pp. 315–316.)

Résumé of the British Association paper, and consequent discussion, on work done during the past four years at Birmingham on the practicability of supplying H.F. power to moving vehicles by induction, thus getting rid of sliding contacts. Poulsen arcs are used as generators, functioning apparently fairly well, but needing more work as to reliability and steadiness. The efficiency of the transformation represented by an overhead system of the type proposed is very good. The mercury arc rectifier functions well even up to a frequency of 107,000 p.p.s. In the discussion, it is suggested that the advantages gained by getting rid of sliding contacts are liable to be exaggerated.

DAS INDUKTIVE ZUGBEEINFLUSSUNGSYSTEM MIT GLEICHSTROMERREGUNG (Inductive train-control with direct-current).—O. Schirm. (*E.T.Z.*, 13th September, 1928, pp. 1357–1361.)

Deals both with theory and practice.

SUR L'UNIFICATION DES SIGNAUX HORAIRES RADIOTÉLÉGRAPHIQUES (The Unification of Time Signals).—G. Bigourdan. (*Comptes Rendus*, 3rd September, 1928, V. 187, pp. 453–457.)

The writer points to the excessive number (about 40) of different systems at present in use over the world, and advocates the adoption of one common one. He proposes and describes a new system which would be serviceable for all purposes.

SFÉROGRAPHE: APPAREIL TÉLÉPHOTOGRAPHIQUE DE LA SOCIÉTÉ FRANÇAISE RADIOÉLECTRIQUE (Sferograph: a telephotographic Apparatus of the S.F.R.).— Chauveau. (*Bull d. l. Soc. Fran. d. Élec.*, August, 1928, V. 8, pp. 835–838.)

A short description of this apparatus for transmitting and receiving pictures by radio, designed to be suitable for use by the general public in that it abolishes the complexities of the other systems—mirrors, photo-electric cells, etc.—and utilises the colouration of an impregnated paper.

LE "TÉLÉTYPE."—Bonnin. (*Bull. d.l. Soc. Fran. d. Élec.*, September, 1928, V. 8, pp. 915–920.)

Description of the teletype instrument, derived from the Baudot System of telegraphy, by which messages are transmitted telegraphically from a typewriter keyboard and reproduced at the other end in typewritten form. The pages following (to 928) describe the system "Télémixte" by which a telephone subscriber can telephone in the ordinary way and then (without making another call) change to the Télétype and leave a recorded message.

ZUR MESSUNG VON NACHHALLDAUER UND SCHALLABSORPTION (The Measurement of Echo-duration and Sound-absorption).—Meyer and Just. (*E.N.T.*, August, 1928, V. 5, pp. 293–300.)

The writers begin by recalling Sabine's results showing the dependence of the acoustic properties of a room on the duration of echoes. They point out that the study of such echoes is important not only from the musical point of view but for testing the sound-absorbing properties of materials, the absorption-coefficients of which can be determined by measuring echo-times of a room with and without the material. They go on to describe a new process for the demonstration and measurement of echo-duration. By the use of a heterodyne hummer and a loud speaker, a compound note (to avoid interference) is produced, whose decay in the room is registered by a Reisz microphone, amplifier and galvanometer. The curves directly confirm the exponential fading away of sound-strength in echo, and allow exact measurement of the echo-duration. Specimen records are given.

THE INTERNATIONAL UNION OF SCIENTIFIC RADIOTELEGRAPHY.—J. H. Dellinger. (*Proc. Inst. Rad. Eng.*, August, 1928, V. 16, pp. 1107–1112.)

A brief general outline of the U.R.S.I. (the 1928 meeting of which took place in Brussels last September) with a more detailed account of the American Section and of last year's meeting in Washington.

CO-OPERATION BETWEEN THE INSTITUTE OF RADIO ENGINEERS AND MANUFACTURERS' ASSOCIATIONS.—A. N. Goldsmith. (*Proc. Inst. Rad. Eng.*, August, 1928, V. 16, pp. 1065–1071.)

An address by the Institute's President before the Convention of Radio Division of the National Manufacturers' Association.

SOME EXPERIMENTS ON WATER-DIVINING.—A. E. M. Geddes. (*Nature*, 8th September, 1928, V. 122, p. 348.)

Recent tests here described lead the writer to conclude: (1) that the faculty of water-divining is possessed by some individuals; (2) that the individual responds to some, at present unknown, external stimuli; and (3) that certain substances can prevent the arrival of those stimuli, in which case the individual cannot respond.

FREQUENZVERFIELFACHUNG DURCH EISENWANDLER (Frequency multiplication by iron frequency transformers). Final Parts.—E. Kramar. (*Zeitschr. f. Hochf. Tech.*, August, 1928, V. 32, pp. 46–58.)

SURGE-VOLTAGE INVESTIGATIONS. (*Elec. World*, 7th July, 1928, V. 92, pp. 5–8.)

Tests were carried out on six important American networks. Values are given for the length of time of the surges and for their voltages. Direction also is discussed. Surges due to lightning and to switching are included. Protection by earthing is discussed without any very definite conclusions.

IMPRESSIONS OF THE BERLIN SHOW. (*Wireless World*, 12th September, 1928, V. 23, pp. 306–310.)

THE SERIES CAPACITOR: Construction and Operation of New Equipment designed to increase Load-carrying Capacity of Line and to improve Voltage Regulation. (*Electrician*, 31st August, 1928, V. 101, pp. 228–229.)

The tuned circuit, so well known in wireless and formerly so carefully avoided in commercial power transmission, is now being used most successfully on the lines of the N.Y. Power and Light Corporation at Ballston. For further illustrations and an editorial on the important future of this device, see also *Gen. Elec. Rev.*, August, 1928.

SOME EXPERIMENTS ON THE LIGHT-SENSITIVITY OF COMMERCIAL SELENIUM CELLS.—G. P. Barnard. (*Proc. Phys. Soc.*, 15th August, 1928, V. 40, pp. 240–248.)

PROCÉDÉ D'OBTENTION DU MAXIMUM DE RAYONS ULTRAVIOLETS À ONDES COURTES (Method of obtaining the maximum short wave Ultraviolet Rays).—N. Iarotzky. (*Comptes Rendus* 3rd September, 1928, V. 187, pp. 459–461.)

By using a special quartz mercury-vapour tube, and voltages of 80,000 instead of the usual 20–80V, the author obtains ultra-violet light with practically no visible or heat rays and containing wavelengths down to $253\mu\mu$—whereas hitherto the shortest has been $579\mu\mu$. From a bactericidal point of view this method possesses great advantages.

SOME NEW APPLICATIONS OF SHORT RADIO WAVES.—J. Taylor and W. Taylor. (*E.W. & W.E.*, September, 1928, V. 5, pp. 503–508.)

THE HEAVISIDE OPERATOR AND THE OPERATIONAL CALCULUS.—W. A. Barclay. (*E.W. & W.E.*, August, 1928, V. 5, pp. 431–436.)

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

PROPRECOJ DE CIRKVITOJ.

EFEKTO DE ANOD-KRADA KAPACITO EN DETEKTOROJ KAJ MALALTFREKVENCAJ AMPLIFIKATOROJ.—W. B. Medlam.

Jen longa artikolo kun tre plena informdona diskutado pri la ĉi-supra temo. La efekto de l'anod-krada kapacito en la detektoro (anod-kurvo) estas unue diskutita, kun ekvivalentaj cirkvitoj por la enmetaj kaj por la elmetaj cirkvitoj, kiel modifita per ĉi tiu kapacito. La rezultanta enmeto sub reakciaj kondiĉoj estas tre plene pritraktita, kaj la efekto ĉe l'agordigo de l'cirkvito laŭ la portondo kaj laŭ ĉiu el la flankgrupoj estas bone klarigita, kaj per matematika rezonado kaj per kurvoj. Ĉi tio kondukas fine al konsiderado pri l'efektiva modulado ĉe krada tensio, montrante la gravan efekton, kiun la reakcio eble havos, kaŭzi distordon je profundaj enmetaj moduladoj.

La diskutado estas poste direktita al la reakcia efekto en malaltfrekvenca (rezisteca-kapacita) amplifado, la argumento estante denove bone ilustrita, kaj per matematika rezonado kaj grafike.

Laste la elimino de reakcia efekto pere de neŭtrodinaj aranĝoj estas konsiderita, unue por la detektoro kaj ankaŭ por la malaltfrekvenca amplifikatoro. Aranĝo estas aparte ilustrita por neŭtrodina " puŝ-tira " detektoro kaj rezistec-kapacita amplifikatoro, eliminanta la efektojn de krad-anoda kapacito en la detektoro kaj amplifikatoro.

SENDADO.

Polusaj Diagramoj Kaŭze de Ebenaj Antenaj Reflektilaj Sistemoj.—T. Walmsley.

La polusa diagramo de radiera sistemo estas kutime planita sole en la horizontala ebeno. Ĉi tiu artikolo derivas formulojn por la polusa diagramo en iu ajn vertikala ebeno, klarigante la bone konatan fakton, ke la kampo malantaŭ la reflektilo estas konsiderinda. La problemo estas, konstati la efekton de reflektilo ĉe ekscita anteno je ĉiu angulo en iu ajn vertikala ebeno. La formuloj estas diskutitaj kaj ilustritaj vektore, kaj rezultoj estas donitaj, montrantaj la polusajn diagramojn de specifita antena reflektila sistemo en la horizontalaj kaj en diversaj vertikalaj ebenoj.

RICEVADO.

La Fina Aŭ Grandpotenca Ŝtupo de Amplifikatoroj.—M. von Ardenne.

La aŭtoro unue konsideras la funkciajn tensiojn, per kiuj la difinita valvo liveras la maksimuman elmeton al iu laŭtparolilo. La limoj de rektlinia karakterizo estas pritraktitaj, kaj la tipo de l'dinamika kurvo kun reakcia laŭtparolila ŝarĝo estas montrita, kaj per ekvacioj kaj per grafika analizo.

La efektoj trans la frekvencoj de l'aŭdebla amplekso estas ankaŭ revuitaj laŭ ilia rilato al ĉi tiu rezonado. La aŭtoro poste pritraktas la rezultojn de ŝoka kuplado, kaj de konekto de laŭtparoliloj paralele kaj serie. Interaliaj, utila konkludo atingita estas ke, per konekto paralele de nombro da identaj valvoj, kaj per konekto paralele de interresponda nombro da laŭtparoliloj, estas eble pligrandigi la enmetan vatkvanton sen la neceso altigi la kradajn aŭ anodajn voltkvantojn. Oni ankaŭ sugestas ke, por obteni kiel eble plej malmultan variadon de frekvenco, estus eble uzi en la elmeta ŝtupo du valvojn, unu kun tre alta, kaj la alia kun tre malalta interna rezisteco, ĉiu el ili funkciiganta sendepende sian propran laŭtparolilon.

La utiligo de la kvinodo (" pentodo ") kiel elmeta valvo estas laste mallonge konsiderita.

HELPA APARATO.

La Desegnado de Ne-Kontaktaj Termo-Kuniĝaj Ampermetroj.—F. M. Colebrook and R. M. Wilmotte.

La artikolo unue diskutas la avantaĝojn de la ne-kontakta tipo de termo-kuniĝa instrumento ; poste paŝas al la ĝeneralaj principoj de desegnado, inkluzive sentemeco kaj konstanteco de kalibrado. Ĉi tio estas sekvita de detala priskribo pri du efektivaj desegnoj evoluigitaj ĉe la Nacia Fizika Laborejo, notinde estante la facileco de riparo aŭ anstataŭigo de la varmiga elemento. La preparado de l'kuniĝoj estas unue diskutita, kun detaloj pri la konstruado, ilustritaj de fotografaĵoj kaj diagramoj. La desegnado de l'varmigilo estas poste pritraktita, kun eksperimentaj rezultoj pri varmigila materialo, kaj pri l'efekto de variado de l'distanco inter varmigilo kaj kuniĝoj. La kalibrado estas ilustrita kaj la artikolo finiĝas per noto pri l'uzado de l'kuniĝoj kiel fonto de konataj radio-frekvencaj potencialaj diferencoj.

Pri l'Aplikado de Kondensatoroj al la Mezurado de Grandaj Radio-Frekvencaj Kurentoj.—P. R. Coursey

La artikolo priskribas la utiligon de kondensatoraj ŝuntoj, kune kun malgrandampleksaj termo-kuplaj instrumentoj por la mezurado de grandaj radio-frekvencaj kurentoj. Post diskutado pri antaŭaj metodoj de tiaj mezuradoj, la aŭtoro montras la kondensatoran metodon, kiu konsistas el kondensatoro serie konektita kun la termo-instrumento, la tuto estante ŝuntita per alia kondensatoro. La teorio de la metodo estas diskutita, kun esprimoj por diversaj valoroj de ŝunto, dum la aplikado de resonanca absorba cirkvito por elimini iun nedeziritan harmonikan frekvencon (kiel kelkafoje okazas je mallongaj ondoj) estas ankaŭ pritraktita. Diversaj komercaj tipoj de tiaj instrumentoj estas montritaj, inkluzive la formo de kondensatora konstruado por stabila kalibrado. Oni diras, ke la indikaĵoj de metroj ĉiuspecaj restas tre konstantaj, tial ke ili povas esti tenitaj kiel normoj por radio-frekvencaj mezuradoj, dum iliaj malgrandaj dimensioj taŭgigas ilin por tre altaj frekvencoj.

DIVERSAĴOJ.

La Aplikado de Enliniigaj Grafikaĵoj al Valvaj Karakterizoj.—M. Reed.

La aŭtoro traktas pri l'utiligo de enliniiga grafikaĵo por obteni la ordinarajn karakterizojn per donitaĵoj pri valva desegnado. La ĝenerala konstruado de l'enliniiga grafikaĵo estas priskribita kaj ilustrita, kaj la kompleta grafikaĵo montrita, el kio estas obteneblaj la jenaj kurvoj :—(1) la kradvoltoj—anodkurenta kurvo, (2) la anodvoltoj—kradvolta kurvo por konstanta anodakurento, (3) la anodvolta—anodkurenta kurvo. Ekzemplo estas ellaborita en kiu la metodo estas uzita por determini la karakterizojn de valvo de difinita impedanco, amplifa faktoro, k.t.p.

Resumoj kaj Aludoj.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

Radio-Ekspozicio ĉe Olympia, 1928a.

Mallonga redakcia artikolo pri la Brita Nacia Radio-Ekspozicio, tenita ĉe Olympia (Londono), de Septembro 22a ĝis 29a. Revuo pri la montraĵoj aperos en la novembra numero.

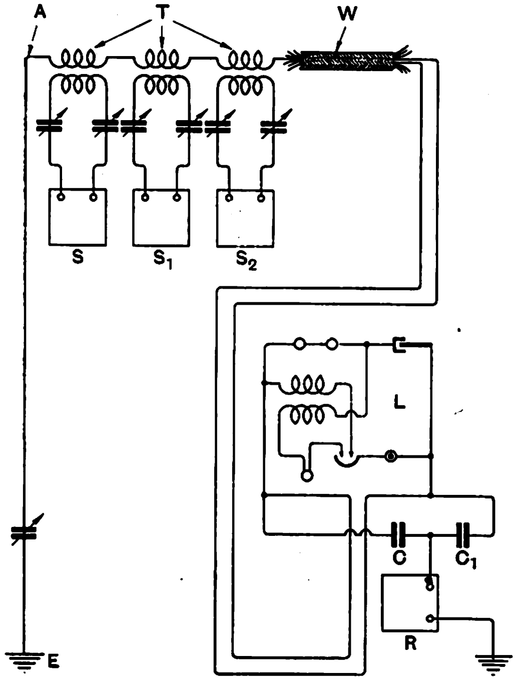
Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

WIRED WIRELESS.

(*Convention date* (*U.S.A.*), *17th July*, 1926. *No.* 274491.)

A limited broadcast or television service is distributed over an existing telephone network by feeding the high-frequency currents into a central unused wire forming part of a cable containing, say, fifty subscribers' lines. Since the cable is sheathed in lead, there will be no stray fields, and as the effective "radiation" between the central radio-frequency wire and the surrounding telephone wires is limited to a distance of an inch or so, the induced currents will be relatively powerful. Such a system could be maintained throughout the hours when the radio broadcast service is not in operation, and could be "metered" and charged for at specified time-rates by the telephone company.



As shown in the figure, one or more studios S, S_1, S_2 feed modulated radio currents through transformers T into a central wire A, which may be tuned and earthed at E. From the wire A the radio-frequency currents are transferred to all the other wires in the cable W. A typical subscribers' loop is shown at L with the H.F. receiving set R branched off from two series condensers C, C_1 of sufficiently small capacity to pass the radio-frequency signals. Such a wired-wireless broadcast service is free from static or fading, offers a dependable selection from two or more programmes transmitted simultaneously on different carrier-frequencies, and does not interfere with the normal use of the telephone.

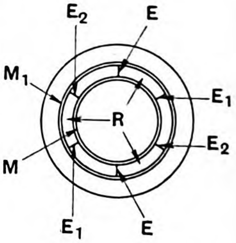
Patent issued to G. O. Squier.

QUARTZ RESONATORS.

(*Convention date* (*Germany*), *24th April. No.* 269935.)

Frequency-control crystals cut in plate or rod form from the mother crystal are liable to oscillate both at certain harmonics of the fundamental frequency and also at several inharmonic or "secondary" frequencies. In order to overcome this source of uncertainty, a ring R is formed from a quartz plate which has been cut perpendicularly to the optical axis. The electrical axes of the ring are shown at E, E_1 and E_2.

When such a ring is subjected to a radial field from two concentric electrodes M, M_1, as shown, it can be demonstrated theoretically and confirmed by experiment that only one single oscillation can be produced, of such a frequency that three whole wavelengths are distributed around the periphery of the ring R. When used to produce the known "luminous" effect at resonance, the phenomenon is much brighter or more pronounced in the case of a ring crystal than with the standard "rod" crystals previously used.



Patent issued to Prof. E. Giebe and Dr. A. Scheibe.

DRY-CONTACT RECTIFIERS.

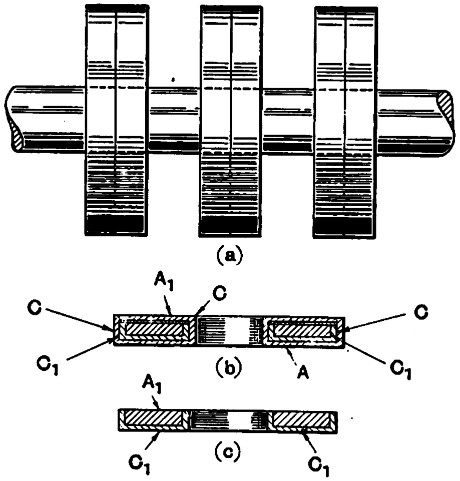
(*Convention date* (*U.S.A.*), *26th August*, 1926. *No.* 276622.)

A number of copper blanks are arranged in pairs upon a central spindle as shown in Fig. (*a*), and are heated until a layer of metallic oxide is formed upon the surface. The blanks are then dismounted and are in the condition shown in Fig. (*b*), where C_1 represents an inner layer of cuprous oxide or red oxide of copper, and C a thinner outer layer of cupric oxide or black oxide of copper.

Owing to the comparative protection of the inner faces of each pair of blanks from the heat, the depth of the coating on the face A_1 will be less than that on the outer face A and sides.

The blank is next treated with a solution of potassium cyanide until the cupric oxide deposit C has been removed from the entire surface, and the process is then continued until the cuprous oxide layer C_1 also has been removed from the inner face A_1, leaving the completed blank in the form shown in Fig. (*c*). The blanks are then re-assembled upon a central spindle under pressure, to form rectifying couples or units in the ordinary way. The method permits the mass production of rectifying elements of consistent standard at relatively small cost.

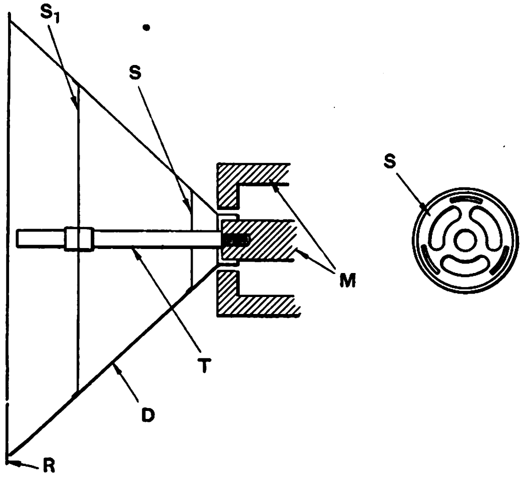
Patent issued to The Westinghouse Brake & Saxby Signal Co., Ltd.



LOUD SPEAKERS.

(*Application date, 22nd April*, 1927. *No.* 294285.)

In a moving-coil loud speaker provision is made to allow the diaphragm to move freely in the line of the "drive," whilst at the same time restraining any lateral movement. This object is achieved by screwing a guide-shaft *T* into the centre pole-piece of the magnetic movement *M* and inserting paper supports or "spiders" *S*, S_1 between it, and the conical diaphragm *D*. The shape of the inner spider *S* is shown in front view at the side of the figure, the outer spider S_1 being of similar design.



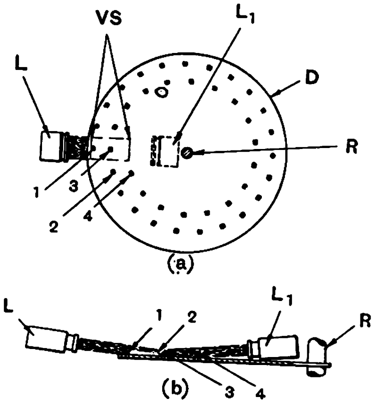
Each spider is perforated at the centre so as to ride freely on the guide-shaft *T*, the outer periphery being gummed or otherwise secured to the inner surface of the vibrating cone *D*.

Patent issued to H. J. Round and N. M. Rust.

TELEVISION RECTIFIERS.

(*Application date, 21st January*, 1927. *No.* 294267.)

In order to increase the brightness of the transmitted image, an exploring device is designed to permit the use of more than one source of light for simultaneously scanning the whole of the object in transmission, or for illuminating the whole of the viewing-screen in reception. Alternatively several sources of light may be used, each localised on different zones or areas of the object or viewing-screen.



The exploring device consists of a disc *D*, Fig. (*a*), rotated about a shaft *R* and pierced with two sets of spirally arranged holes. One spiral commences at 1 and ends at 2, whilst the other extends from 3 to 4. As shown in section in Fig. (*b*) the holes are fitted with small mirrors, those of the spiral set 1, 2 being inclined outwards so as to reflect the rays of light from a lamp *L*, whilst those of the spiral set 3, 4 incline inwards towards the shaft *R* and reflect rays from a second lamp L_1.

Assuming that the illumination of each lamp is controlled by the incoming signals, then the resulting fluctuations of light are thrown in proper sequence by the disc *D* on to a viewing screen *VS*, Fig. (*a*), so as to reproduce the original televised scene, the spiral set 1, 2 traversing the left-hand half of the screen, whilst the spiral set 3, 4 covers the right-hand half.

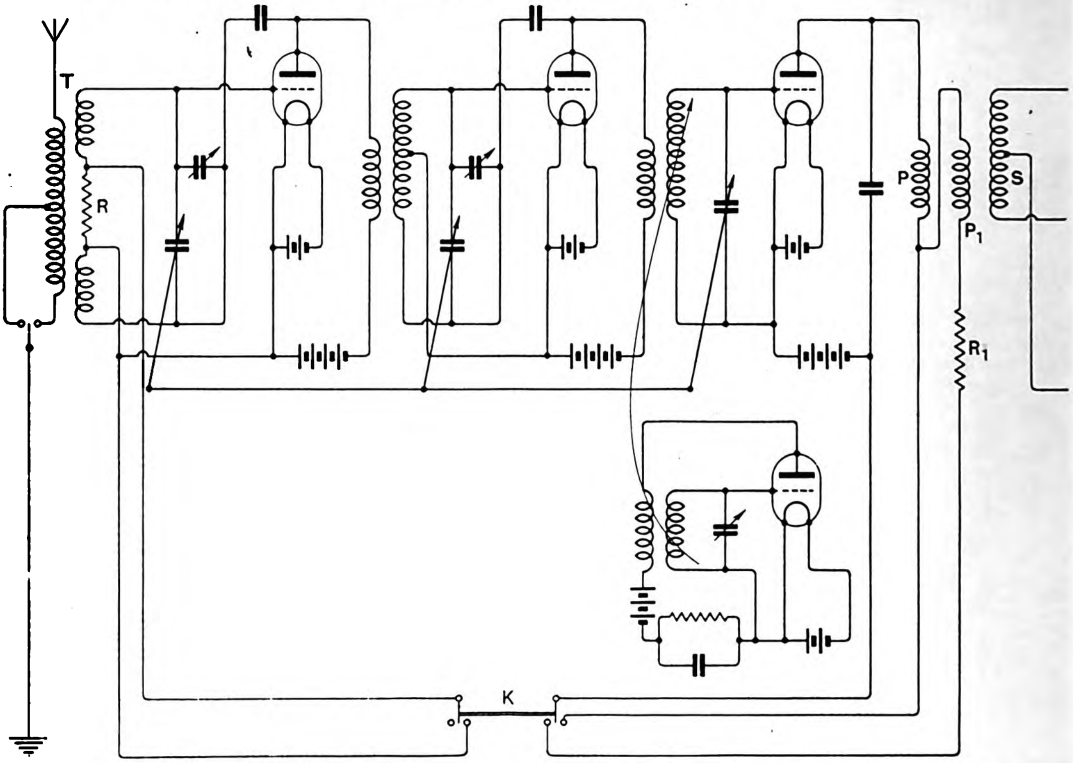
Patent issued to Television, Ltd., and J. L. Baird.

LONG AND SHORT RANGE RECEIVERS.

(*Convention date* (*U.S.A.*), 23*rd May*, 1927. *No.* 291014.)

High selectivity for long-distance working is, in general, incompatible with fidelity of reproduction from the local station. If the full width of the modulation sidebands are covered when receiving from the nearby station, the selectivity of the set cannot be sufficient to separate other and more distant stations, spaced apart, say, by the standard frequency-gap of 10 kilocycles. The circuit illustrates an arrangement in which a set is switched over from high-quality reproduction of a local programme to selective reception from more distant stations.

The input transformer *T* comprises a resistance *R*, whilst the output transformer from the detector valve comprises two primary windings, one P_1 being more closely coupled to the secondary *S* than the other P_1, together with a resistance R_1. When the switch *K* is in the right-hand position, the input resistance *R* is short-circuited, whilst the closely-coupled winding P_1 and the resistance R_1 in the output transformer are open-circuited, giving high selectivity with poor fidelity. In the position shown, the windings *P* and P_1 and the resistance R_1 are in series, and give good-quality reproduction with poor selectivity. By removing the short-circuit on the resistance *R*, the quality may be still further improved.

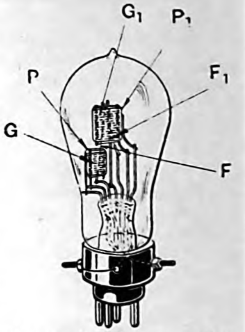


Patent issued to The British Thomson-Houston Co., Ltd.

MULTISTAGE VALVES.

(*Application date* 19*th May*, 1927. *No.* 295079.)

A single filament is surrounded at different parts of its length by two separate sets of electrodes of different sizes so that one set may serve as a detector, for example, and the other as a power-amplifying stage. The filament is V-shaped, one leg *F* being longer than the other F_1. If the filament supply is at 6 volts, the smaller set of electrodes *P*, *G* are arranged around the negative end of the filament, and the larger set P_1, G_1 at the positive end. By connecting the common grid return lead for both stages to the negative battery terminal, a grid bias of suitable value is automatically applied to the grid of each stage, that applied to the grid G_1 being greater than that applied to the grid *G*.



More than one set of electrodes, such as *P*, *G*, may be mounted around the longer leg of the V-shaped filament. The grid electrode of the smaller set may be extended towards the plate of the larger set of electrodes, thus creating a certain degree of favourable interaction between the stages. As the set P_1, G_1 co-operates with a greater length of filament than the set *P*, *G*, the available emission is sufficient to give rise to effective power-amplification.

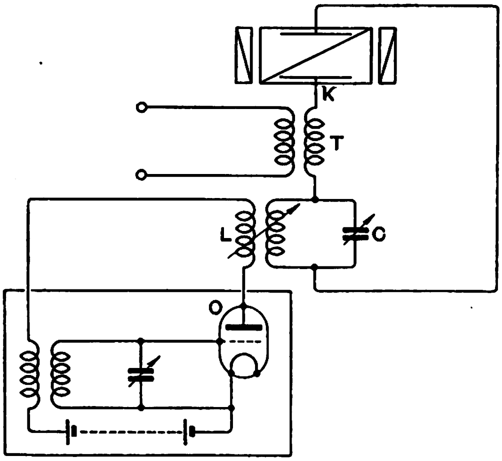
Patent issued to The British Thomson-Houston Co., Ltd.

PICTURE TELEGRAPHY.

(*Application date 26th May,* 1927. *No.* 296124.)

It is well known that the response of a Kerr cell or "light valve" as commonly used in high-speed picture telegraphy, varies as the square of the voltage applied across its electrodes, instead of linearly. In order to minimise the resulting distortion, it has been proposed to use a steady biasing voltage, but this gives rise in course of time to a brownish deposit or sludge which affects the efficiency of the optical cell as a whole.

According to the present invention, an approximately linear response is secured by applying a separate high-frequency biasing potential, instead of a steady voltage. As shown in the Figure, incoming signals are applied to the Kerr cell *K* across a transformer *T*, whilst a separate oscillating valve *O* applies a high-frequency biasing voltage through a tuned circuit *LC*, so that at any moment the operative voltage across the cell electrodes is the algebraic sum of the signal and local oscillations.



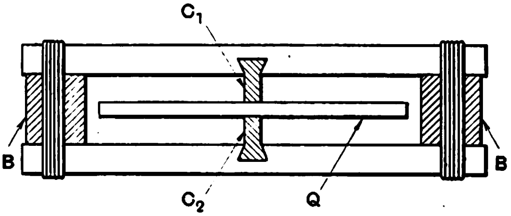
Patent issued to G. M. Wright.

PIEZO-CRYSTAL MOUNTINGS.

(*Application date 27th May,* 1927. *No.* 295081.)

Experience has shown that quartz crystals when used as frequency standards are prone to exhibit irregularities in frequency, due either to the manner of support or to the cleanness and dryness of the crystal, the aberrations probably arising from electrostatic losses occurring on the surface of the crystal. Changes of decrement, which take place simultaneously with changes of frequency, may be due in part to the frictional loading which occurs when a crystal is mounted with its opposite faces in contact with the electrodes and supports, and in part to the loading or pressure of the surrounding atmosphere.

According to this invention, a quartz resonator is so mounted that it is clamped only at parts of its surface that are substantially nodal zones, thus preventing any rocking motion about a central axis. "Air loading" may be avoided by housing the crystal unit as a whole within an evacuated vessel, from which every trace of moisture has been removed, thus eliminating any dielectric losses due to surface moisture. As shown in side elevation, the crystal *Q* is held between two clamping members C_1, C_2 dovetailed into the upper and lower electrodes. Spacing blocks *B* of fused quartz hold the electrodes apart, and are secured by a wrapping of silk.



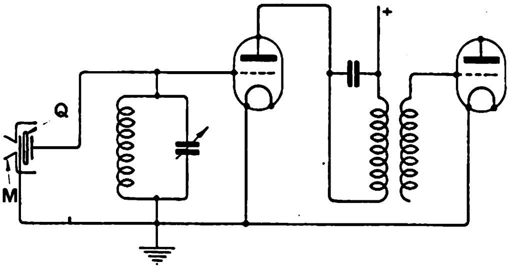
Patent issued to H. J. Lucas.

FREQUENCY MODULATION.

(*Application date 17th March,* 1927. *No.* 295957.)

Instead of transmitting a signal by causing the microphone current to vary the amplitude of the carrier waves, the frequency of the latter may be altered in rhythm with the signal, the amplitude remaining constant. The method is of general application. For instance, when transmitting optical effects, the carrier frequency is varied in accordance with the intensity of a source of light or with varying colours. Reception is effected by causing the incoming frequency variations to shift the working point of the valve up and down the slope of the resonance curve of the input circuit, thus creating an output current quantitatively proportional to the incoming frequency changes.

According to the present invention, the mean frequency of the transmitted carrier-wave is maintained constant by a piezo-electric oscillator, preferably at a point half-way between the top and bottom of one side of the "crevasse" on the crystal resonance curve. In transmission for example, one of the electrodes of the crystal *Q* may be the movable diaphragm of a sound box or microphone *M*. The frequency of the crystal, and therefore of the transmitted carrier-wave, will change with the width of the gap between the electrode and the crystal, though the mean frequency as well as the amplitude of the carrier remains constant.

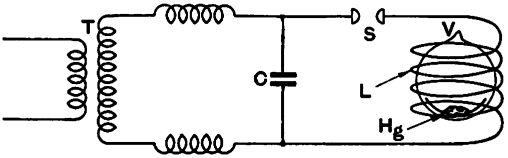


Patent issued to J. Robinson.

SHORT-WAVE RADIATION.

(*Convention date* (*U.S.A.*), *9th April*, 1926. *No.* 269161.)

Ultra short-wave energy, ranging from the visible to the infra-red region of the spectrum, is generated by passing high-frequency currents through a coil surrounding a vessel *V* containing a quantity of mercury, together with mercury vapour, and an added gas such as argon, in which the mean free path of the molecules is shorter than that of the mercury vapour. The presence of the argon facilitates the production of free electrons by collision, and thus enables the radiation of energy to be initiated.



An intense high-frequency field is set up in the coils *L* by the discharge through a spark-gap *S* across a condenser *C* fed from a step-up transformer *T*. The applied field induces ionization by collision, and an absorption of energy, which is subsequently given off as radiation until a balanced or stable condition is reached, depending upon the quantity and pressure of gas in the vessel *V* and other characteristics. Infra-red oscillations varying from 0.05 cm. to 0.3 cm. wavelength can be generated in this way.

Patent issued to The British Thomson-Houston Co., Ltd.

TELEVISION BY INVISIBLE RAYS.

(*Application date*, *26th January*, 1927. *No.* 294671.)

The image of the televised scene is projected solely by means of ultra-violet or infra-red light on to a phosphorescent or fluorescent screen. The use of X-rays is specifically excluded. The screen may be coated with the sulphide or platino-cyanide of barium, or with sulphate of quinine; or a fluorescent liquid, such as paraffin oil may be used in a container which is transparent to the invisible radiation by which the projection is effected, and also transparent to normal light by which the projected image is seen by the observer.

Again, a fluorescent vapour,for example, that of sodium, contained in a similarly transparent vessel may be used as a viewing screen. Still more interesting effects, it is stated, may be obtained by projecting the image on to a free cloud of fluorescent vapour. The operation need not take place in the dark, for the screen and its surroundings can be illuminated by visible light from which the invisible components (*i.e.*, the ultra-violet and infra-red rays) have been fiiltered out.

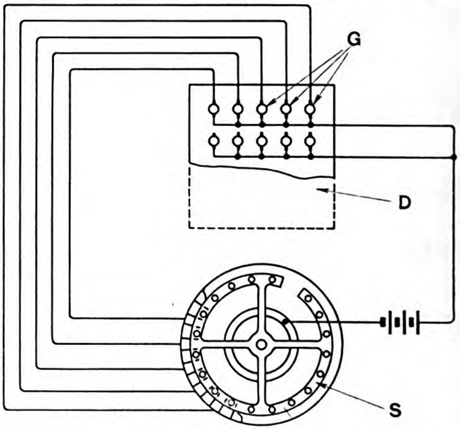
Patent issued to Television, Ltd., and J. L. Baird.

TELEVISION APPARATUS.

(*Application date*, *3rd March*, 1927. *No.* 293,474.)

Instead of scanning or analysing the object to be televised through a rotating disc, fitted with spiral holes or lenses, a more rapid effect is secured by utilising a stationary plate pierced by a large number of holes, each of which is obturated in turn by means of a small spark-gap. The arrangement is based on the fact than an electric discharge or spark taking place across the path of a ray of light absorbs or prevents the passage of the light.

Light from the object to be televised is focused upon a plate *D*, provided with a number of holes. In front of each hole is located a small spark-gap *G* suitably connected to a distributing switch *S*.



The switch is so arranged that at any one moment all the gaps are active (and therefore opaque to the focused light) except one. The position of the latter or "free" gap is then, in effect, moved progressively and at high speed along the series of holes, thus throwing a point image of each portion of the object in rapid succession upon a sensitive cell (not shown). The described arrangement is free from the speed limitation necessarily attaching to any mechanically-moving analyser, such as the familiar rotating disc.

Patent issued to W. Dawson and D. M. Milner.

EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER

VOL. V. DECEMBER, 1928. No. 63.

Editorials.

Radio Transmission and the Upper Atmosphere.

FOR many years after Heaviside and Kennelly first suggested that the upper atmosphere played an important part in long-distance radio telegraphy our ideas as to the exact role played by the ionised layer were very vague. If the layer were conducting it would act as an upper guide just as the earth acted as a lower guide and the waves would spread out in the thin atmospheric spherical shell between them, thus causing much less attenuation over large distances than would have been the case had the waves been free to radiate into space. All long-distance communication was at that time carried out with very long waves and this simple explanation seemed to fit in fairly well with the observed phenomena. The very long ranges sometimes obtained with shorter waves could hardly be explained by reflection at the surface of a layer, but Dr. Eccles' theory that the waves entered the layer and were refracted in it owing to their velocity being greater in the ionised medium than in the un-ionised atmosphere offered an alternative explanation which has proved very fruitful in its further development. That was in 1912, and although little progress in our knowledge of the subject was made during the War, the last few years have seen phenomenal strides in what might be called the technique of the wireless investigation of the upper atmosphere.

Different methods have been used by different investigators and it was questionable to what extent these various methods might be expected to give concordant results. Did the so-called equivalent height of the ionised layer as determined by one method mean exactly the same thing as the equivalent height as determined by another method ? This question has been investigated very thoroughly by Prof. E. V. Appleton, who communicated a paper on the subject at the Brussels meeting of the Union Radio Scientifique Internationale in September and again recently at a meeting of the Physical Society. The investigation is necessarily highly mathematical but the results can be explained fairly simply.

Three Comparative Methods.

Three methods are compared, viz., the wavelength change method, the angle of incidence method, and the group-retardation method.

The first method was proposed and developed by Appleton and Barnett. The carrier wave of a transmitting station reaches a distant receiving station by two paths, one along the ground and the other via the upper atmosphere ; if these two rays arrive in phase the signals have a maximum intensity, if they arrive in opposition the signals have a minimum intensity. If now the transmitting station gradually increases or decreases its wavelength, the received signal passes through successive maxima and minima and the change of wavelength necessary to pass from one maximum to the next enables one to calculate the difference of path of the two rays and thus, on certain assumptions, to deduce the height of the ionised layer.

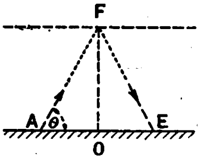


Fig. 1

The second method—a fairly obvious one—also proposed by Appleton and Barnett, and used both by them and by Smith-Rose and Barfield, consists in determining the angle at which the downcoming wave arrives at the receiving station. Assuming reflection at an upper horizontal surface, this suffices to fix the height of the surface.

The third method was proposed and used in the United States by Breit and Tuve. They sent out very short pulses and measured the interval elapsing between the arrival of the pulse by the ground path and the atmospheric path.

What the Different Methods Revealed.

If the atmospheric ray travelled with a constant velocity until it met the lower surface of an ionised layer and were there reflected as shown in Fig. 1, all three methods would necessarily give the same result for the height OF, unless the reflection introduced a change of phase which varied with the wavelength. If, however, the ray enters the ionised layer, and, due to the increasing ionisation and consequent increasing velocity with increased height, is refracted along such a curved path as BCH in Fig. 2, it is by no means evident that the three methods should give the same result, in fact, at first sight, it looks rather improbable. It is interesting, therefore, to know that a complete theoretical investigation shows that all three methods should lead to the same value of the equivalent height of the layer, so that, if Fig. 1 be drawn to give the path difference $AFE - AOE$ calculated from the observations of the first or last method, not only should they both give the same equivalent height OF, but the angle θ should be the same as the angle θ_1 (Fig. 2) observed by the second method, and the point F_1 should coincide with the point F.

When a train or group of waves enters the ionised medium we must be quite clear in our minds as to the meaning to be attached to the velocity of the waves. In an article on "Phase and Group Velocities in an Ionised Medium" (Vol. 4, p. 259, May, 1927) we explained that if one earmarks any hill or dale in the wave, one finds that it is moving with a higher velocity than it did in un-ionised air, that is, with a velocity greater than C, the velocity of light. It is due to this that the ray is refracted downwards and emerges again from the ionised layer. If, however, one regards a group of waves as a whole, one finds that the head or tail of the group is moving with a velocity less than the velocity of light. If the refractive index of the ionised medium be called μ—something a little less than unity—the phase velocity will be c/μ, and the group velocity $c\mu$. The refractive index gradually decreases as one penetrates the ionised layer.

As the ray follows the path BCH in Fig. 2 its phase velocity is greater than c, and on emerging at H its phase will correspond to some path less than BCH, that is to say, its optical path is less than its actual path. In mathematical language its real path is $\int ds$, whereas its phase on emerging at H corresponds to a path $\int \mu ds$. How then can the first method, which depends on the phase of the wave arriving at E, give a result indicating an effective height OF_1, for the path BF_1H is obviously longer than BCH? The answer to this is that the first method does not depend on the phase of the arriving wave, but on the change of its phase when the wavelength is changed—a very important distinction. The refractive index of the ionised medium depends on the wavelength and therefore when the wavelength is changed, the ray changes its path and the integral $\int \mu ds$ gives a different value. Analysis shows that this apparent complexity leads to the surprisingly simple and satisfactory result that the equivalent height as usually calculated by the first method, neglecting the change of path, gives the value OF_1 obtained from the angle of the downcoming wave.

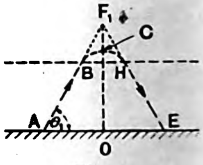


Fig. 2

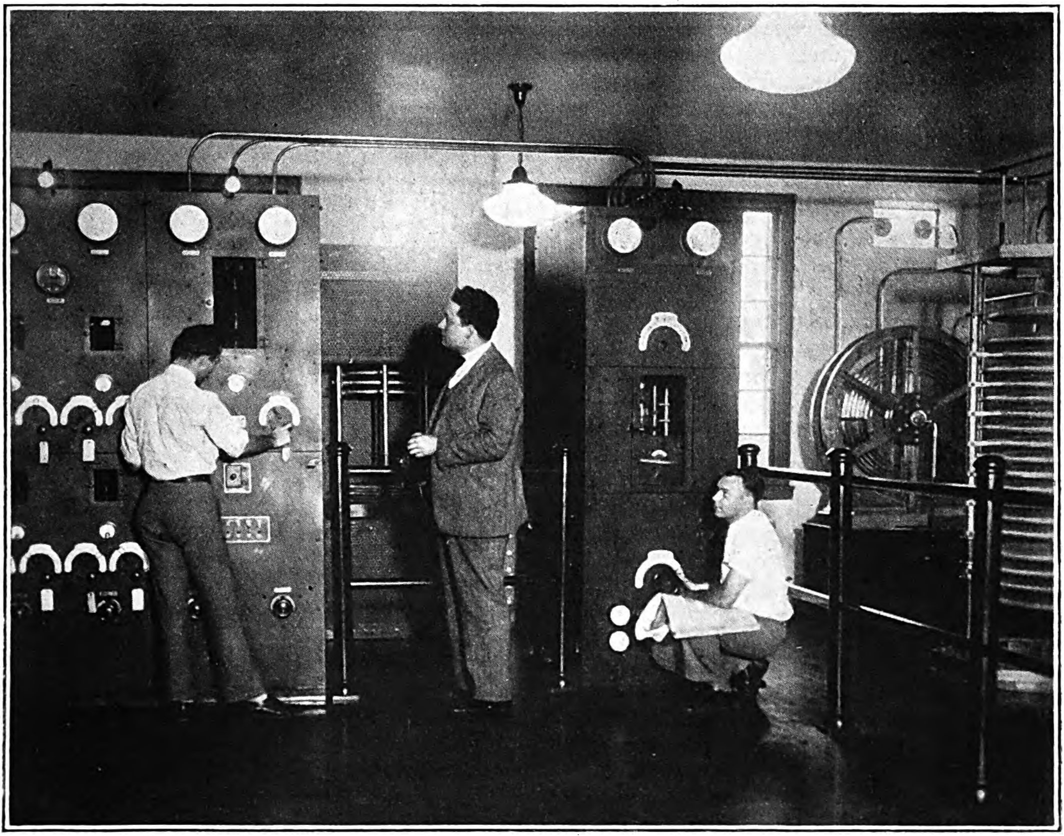
The third method takes no account of the phase of the wave arriving from the atmosphere, but depends only on the time of arrival of the group of waves constituting the pulse. Now this depends on the group velocity which, as we have seen, is decreased in the ionised medium so that the time elapsing between the ray entering the ionised layer at B and leaving it at H corresponds to a path longer than the actual path BCH; the actual path is $\int ds$, whereas the equivalent path is $\int \frac{ds}{\mu}$. Here again analysis shows that the method leads to the same result as the other two methods, because this slowing down makes the time taken along the path BCH exactly the same as it would have been along the path BFH at the velocity of light.

Hence, neglecting any effect that the earth's magnetic field may have on the problem, all three methods should give the same value OF_1 for the equivalent height of the ionised layer, but this is a greater height than the refracted ray ever reaches.

G. W. O. H.

Completion of the Volume.

The present issue completes the year's volume of *Experimental Wireless* and readers will see that we have made arrangements which have enabled us to include the index to the volume and the special index to the year's abstracts in this number instead of waiting for the January issue before incorporating this information, as was done in the case of the last volume. This obviates the necessity of detaching the index from the January number for binding purposes.



WEAF, which has recently changed its wavelength from 491.5 *to* 454.3 *metres. The station is crystal controlled and the wavelength change took place without interruption in the service.*

The Graphical Estimation of Low-frequency Choke Amplifier Performance.

By W. A. Barclay, M.A.

OF the different kinds of valve characteristic graphs now in common use, the plate voltage-plate current type is perhaps the most generally serviceable to the experimenter. This form of valve characteristic has already been fully described in the pages of this journal (see *i.a.*, the articles by Mr. E. Green of July-Aug. 1926 and Aug. 1927), while in a recent note on "Calculations for Resistance Amplifiers," Mr. A. L. M. Sowerby utilised this characteristic to derive the best values of resistance, etc., suitable for given conditions of amplification. It is natural to inquire if by means of an analogous procedure similar optimum values might be obtained for the case of choke-coupled L.F. amplification. Unfortunately, any direct solution of this problem is rendered impossible by reason of the increased number of variables of which we have to take account. Whereas in the case of a resistance amplifier (neglecting coupling capacity) all frequencies are theoretically amplified in the same proportion, the same does not hold true for a choke. In addition, the constants of the choke itself are two, an inductance and a resistance, so that we have now three variables to consider instead of one.

We must, then, fall back on some indirect means of ascertaining which values of our components are likely to give best results, and for this purpose there is nothing for it but to take several arbitrary values of the choke constants and frequency, deducing from them and the characteristics of the valve the best conditions of operation which will give good amplification without distortion. Normally, the amount of arithmetical labour entailed in doing this work is entirely prohibitive, and, however regrettable it may be, the sad fact remains that the ultimate selection of choke, valve and voltage values to be used is usually made without due regard to securing the greatest possible efficiency. To provide a rapid means of estimating and comparing amplifier performance for selected values of voltage, frequency and choke is the object of the present article.

The subject-matter which follows arranges itself naturally into three parts. The first of these is devoted to a statement of the problem to be solved, the true nature of which is not always appreciated by the experimenter. The second describes a simple graphical construction which has been devised by the writer to solve the problem. The last section contains a mathematical analysis of the problem and proof of the construction.

1. The Problem Stated.

On the plate voltage-plate current diagram, the individual values of grid potential appear as curves which are approximately linear over a considerable portion of their length. Within this linear field the characteristics may be represented by the equation

$$i_a = \frac{e_a - E_o + \mu_o e_g}{R_o}$$

where the symbols have their usual significance. In particular, E_o is that value of voltage in which the straight portion of the characteristic $e_g = 0$, if produced, would meet the voltage axis (a result equivalent to putting $e_g = 0$ and $i_a = 0$ in the above equation). Further, let $I_{\text{min.}}$ denote that value of anode current below which the characteristics are curved, and above which, consequently, is situated the linear field of the diagram. Then the conditions for distortionless amplification are expressed by saying that the working point of the diagram must confine its excursions to the linear field above $I_{\text{min.}}$, and that no grid current must be allowed to pass. This second condition is secured in practice by confining the movements of the point to the right of the curve for $e_g = 0$, *i.e.*, by ensuring that the grid voltage e_g is always negative. For choke-coupled amplification the working point will describe an ellipse the position and dimensions of which depend on various factors, such as signal strength, H.T. voltage, the choke constants, and the frequency (see Fig. 1). At any particular frequency the working point describes the corresponding ellipse once in every cycle of oscillation, and in its progress relates pictorially the values of plate voltage, e_a, anode current, i_a, and grid voltage, e_g, which obtain at every instant of the cycle. It is proved in the subsequent analysis that, subject to the two conditions before-mentioned, the variation of all three of these quantities is uniformly sinusoidal, so that a true amplification of signals at that frequency is obtained.

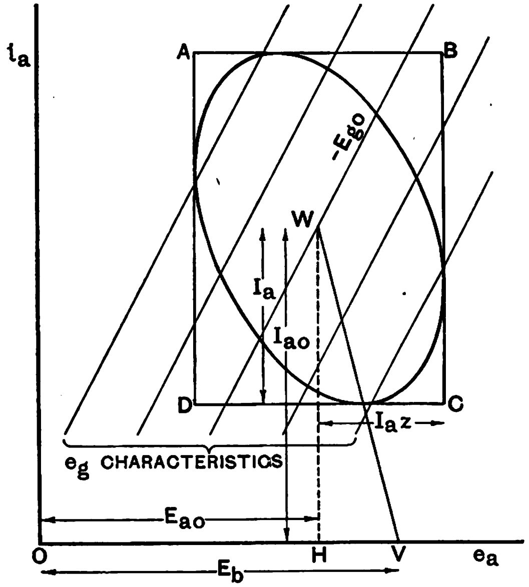


Fig. 1.—*Showing the elliptical locus of the working point on the i_a-e_a diagram of L.F. choke amplifier.*

If L and R denote the inductance and resistance of the choke, and f the frequency, we may write for the ohmic value of the choke impedance $z = \sqrt{R^2 + \omega^2 L^2}$, where ω as usual denotes $2\pi f$. Then, if a rectangle $ABCD$ be described about the working ellipse of Fig. 1 with sides parallel to the axes, it will be shown later that the ratio of the voltage represented by AB to the current represented by AD is a measure of z; *i.e.*, the slope of the diagonal BD is proportional to $1/z$. The actual size of the ellipse, of course, is determined by the signal strength; when this is zero, *i.e.*, when no signals are passing, the ellipse collapses to its central point W. This point represents the initial or steady values of the quantities, which may be denoted by the symbols E_{ao}, I_{ao}, and E_{go}. When no signals pass, the steady current I_{ao} through the choke will cause a potential drop across it of RI_{ao}, and if E_b denote the H.T. battery voltage we have immediately

$$RI_{ao} = E_b - E_{ao} \qquad .. \quad (1)$$

If the points H and V represent the values of E_{ao} and E_b respectively on the voltage axis, we shall have

$$\frac{HW}{HV} = \frac{1}{R}.$$

We see, therefore, that if through V a line of slope $-\frac{1}{R}$ be drawn, the centre W of the ellipse will lie somewhere on this line, its precise situation being dependent on the value of grid bias in use, as represented by the particular negative E_{go} line chosen to intersect it. We have, then, to seek for some means of obtaining the most suitable value of grid bias for the given conditions of operation.

It is clear that the number of possible rectangles with inscribed ellipses that may be drawn is infinite, and that without more data to go on the choice of a particular curve must be entirely arbitrary. Now, the size of the ellipse depends on the amplitude of the signal, and as in all cases we wish the signal to be the maximum possible, we shall assume in what follows that the ellipse found is that for the greatest available amplitude without overload. At this point we call to mind the two limiting conditions—*viz.*, the maintenance of negative grid potential and the maintenance of the anode current at a value greater than $I_{\min}$.

The problem is, then, to find the centre and dimensions of the ellipse for greatest signal strength which will represent without distortion at a given frequency the working locus of a given choke and using a given H.T. voltage, the curve being constructed to touch but not pass the grid curve $e_g = 0$, and to touch but not pass the anode current line $i_a = I_{\min}$. The centre when found will indicate the necessary grid bias to apply for the distortionless amplification of signals of the given strength and frequency.

It should be remarked that this curve and the values obtained from it are not necessarily those which provide the maximum possible voltage amplification for a given signal input. As already remarked, this is a further problem which can only be solved by a comparison of the data which it is the object of this article to ascertain rapidly and conveniently.

2. The Graphical Solution.

The following graphical solution will be found extraordinarily simple, considering the complexities of the problem. Let axes be prepared as in Fig. 2, where values of resistance are taken to any suitable scale on OX, and values of voltage to any desired unit on OY. Then current values will be represented by the gradients of lines drawn through the origin; *e.g.*, the current flowing through a resistance R due to an impressed voltage v will be shown by the gradient of the line OP, where P is the point whose co-ordinates are (R, v). The values of current are most easily set out as graduations on a vertical line RQ, drawn perpendicular to OX beyond the usual limits of the diagram. Thus the current value of the line OP is simply read by extending it to meet this line at Q. It will be found convenient to assign such a position to the vertical line RQ of Fig. 2 that the graduations upon it will be set out to the same scale as the values of i_a in the $i_a - e_a$ diagram. This latter diagram may then be placed beside it as in Fig. 3, so that the two scales of i_a are in juxtaposition. If, further, the scale of voltage upon OY has been chosen the same as that of the voltage axis of the $i_a - e_a$ diagram, the range of values shown by the two diagrams will be identical.

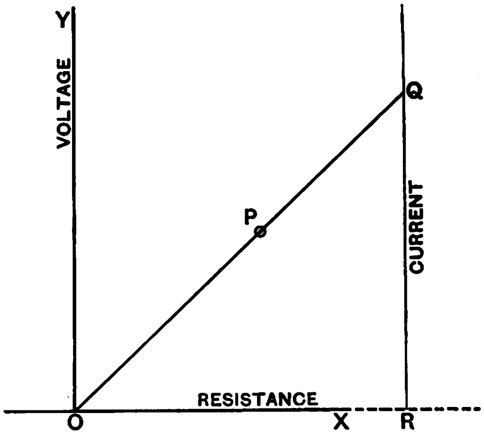


Fig. 2.—*The gradient of OP is a measure of current.*

Let us now define the symbol Z as numerically equal to $\sqrt{(R + R_0)^2 + \omega^2L^2}$, R_0 being, of course, the internal A.C. resistance of the valve over the "straight" portion of the characteristic. We then proceed as follows (see Fig. 3):

Set out downwards from O on OY' a distance equal to ωL ohms measured in terms of the resistance scale. From this point set out parallel to OX distances equal to R and R_0 respectively as shown. The diagonal lines from O will then measure z and Z ohms.

From O on $X'X$ take $OH = -Z$, $ON = z$, $OM = R + R_0$.

Draw the slope line OA for $I_{\text{min.}}$, and take A on it of abscissa $(R + R_0)$.

Next, find B, the point of co-ordinates $(-Z, E_b - E_0)$, so that HB is equal to the distance VE_0 on the $i_a - e_a$ diagram.

Through C, the intersection of AB and OY, draw KD parallel to XX' to meet HB in K and MA in D. Then the slope of OD represents I_{ao}.

Thus, on the $i_a - e_a$ diagram the centre W of the ellipse is found on the line VW by means of its intersection with the dotted line through I_{ao}.

Further, if NFG be drawn through N parallel to OY to meet the slope lines in F and G, the distance FG will represent to scale the maximum peak variation of anode voltage from its mean value, *i.e.*, FG will be one-half the base measurement of the required rectangle. This may now readily be drawn in about W as centre and standing on the $I_{\text{min.}}$ line as base. The curve itself may also now be inscribed as shown in Appendix I, and will be tangential to the characteristic $e_g = 0$. The value of necessary grid bias for this particular signal is given by $-E_{go}$, the value of the characteristic passing through W.

As a check on the work, the voltage measured by BK should be found equal to $\mu_0 \times E_{go}$, where μ_0 is the amplification factor of the valve.

By this means, using a given choke,

frequency, and H.T. voltage, the ellipse corresponding to the maximum possible signal strength capable of amplification without distortion is quickly obtained. If any factor, *e.g.*, frequency, is varied, the corresponding changes in the elliptical path may be ascertained with surprising rapidity. The fact that the characteristic $e_g = 0$ is always tangential to the curves makes this method one of particular utility in the study of amplifier performance. The ellipse need not, of course, be drawn in. The position of the centre W having been found, the grid bias to be applied is read off, while the length of FG is also noted. Comparison of various conditions will soon indicate the best values for use.

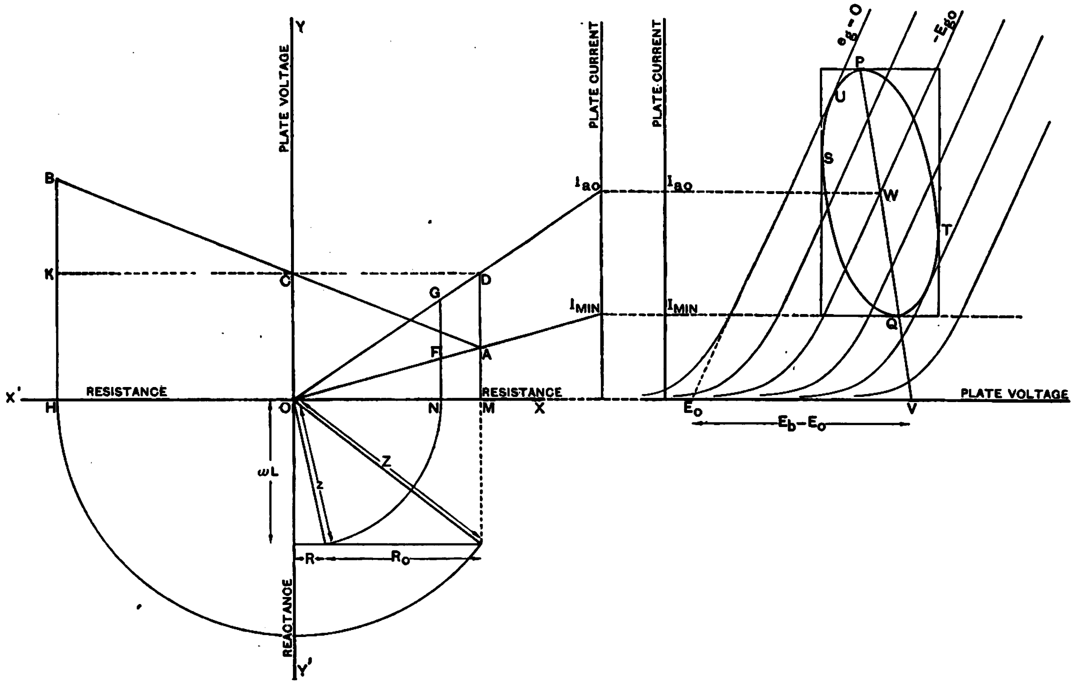


Fig. 3.—*Method of construction of the working ellipse.*

(*N.B.—It is important to notice that the reactance ωL is set out along OY′ for convenience only, and to avoid the necessity of a separate diagram to determine z and Z.*

3. Mathematical Analysis.

We now proceed to an analytical derivation of the above construction. It is known that if an alternating current $i = I \sin \omega t$ pass through a choke of inductance L and resistance R, the P.D. across its ends at any instant is given by the formula

$$e = Iz \sin (\omega t + \phi),$$

where $z = \sqrt{R^2 + \omega^2 L^2}$ and $\phi = \tan^{-1} \frac{\omega L}{R}$.

Hence, if a current represented by

$$i_a = I_{ao} + I_a \sin \omega t \qquad .. \quad (2)$$

pass through the anode circuit of Fig. 4, E_b being the applied H.T., we may write for the instantaneous voltage on the anode,

$$e_a = E_b - I_{ao}R - I_a z \sin (\omega t + \phi) \qquad .. \quad (3)$$

The equation of the Working Locus.

This is obtained by eliminating t between (2) and (3) as follows:

$$(e_a - E_b + I_{ao}R + I_a z \cos \phi \sin \omega t)^2 = I_a^2 z^2 \sin^2 \phi \, (1 - \sin^2 \omega t)$$

i.e., $$(e_a - E_b + I_{ao}R + (i_a - I_{ao}) z \cos \phi)^2 = z^2 \sin^2 \phi \, \{I_a^2 - (i_a - I_{ao})^2\}$$

Transferring the origin to the centre, $(E_b - I_{ao}R, I_{ao})$, the equation becomes

$$(e_a + i_a z \cos \phi)^2 = z^2 \sin^2 \phi \, (I_a^2 - i_a^2) \qquad (4)$$

which is an ellipse centred at the origin.

Dimensions of the Circumscribing Rectangle.

By differentiation of equation (4),

$$\frac{di_a}{de_a} = -\frac{e_a + i_a z \cos\phi}{z^2 i_a + e_a z \cos\phi}.$$

Then it may be shown that

$$\frac{di_a}{de_a} = 0 \text{ when } i_a = \pm I_a$$

$$\frac{di_a}{de_a} = \infty \text{ when } e_a = \pm I_a z.$$

Hence the sides of the circumscribing rectangle are $2I_a$ and $2I_a z$, while the gradient of the diagonal is $\frac{1}{z}$.

Derivation of Mean Anode Current.

The equations of the straight portions of the grid voltage characteristics may be written

$$i_a = \frac{e_a - E_0 + \mu_0 e_g}{R_0}$$

or $$\mu_0 e_g = i_a R_0 - e_a + E_0 \quad .. \quad (5)$$

Substituting in (5) the values of i_a and e_a given by (2) and (3), we obtain for the value of grid voltage e_g at instant t:

$$\begin{aligned}\mu_0 e_g &= R_0(I_{ao} + I_a \sin\omega t) - E_b + I_{ao}R \\ &\qquad + I_a z \sin(\omega t + \phi) + E_0 \quad .. \quad (6)\\ &= \{I_{ao}R_0 - E_b + I_{ao}R + E_0\} \\ &\qquad + \{I_a R_0 + I_a z \cos\phi\} \sin\omega t \\ &\qquad + \{I_a z \sin\phi\} \cos\omega t \\ &= \mu_0 E_{go} + \mu_0 E_g \sin(\omega t + \psi) \quad .. \quad (7)\end{aligned}$$

where

$$-\mu_0 E_{go} = (E_b - E_0) - I_{ao}(R + R_0) \quad .. \quad (8)$$

$$\begin{aligned}\mu_0 E_g &= I_a\sqrt{R_0^2 + 2R_0 z \cos\phi + z^2} \\ &= I_a\sqrt{R_0^2 + 2R_0R + R^2 + \omega^2L^2} \\ &= I_a Z \quad .. \quad .. \quad .. \quad .. \quad (9)\end{aligned}$$

and $$\begin{aligned}\psi &= \tan^{-1}\frac{z\sin\phi}{R_0 + z\cos\phi} \\ &= \tan^{-1}\frac{\omega L}{R_0 + R} \quad .. \quad (10)\end{aligned}$$

where $-E_{go}$ represents the steady component of voltage on the grid, and E_g the amplitude of grid voltage variation. Thus the variation of all three quantities, i_a, e_a, and e_g takes place in simple harmonic manner.

Now, I_a, the amplitude of the varying component of plate current should never exceed the difference between the steady component I_{ao} and $I_{\text{min.}}$. For greatest I_a, therefore,

$$I_a = I_{ao} - I_{\text{min.}}.$$

Again, the numerical value of E_g, the amplitude of the varying component of grid voltage should never exceed the difference between the steady value $-E_{go}$ and zero. Hence we can write, for maximum permissible grid swing,

$$-E_{go} = E_g$$

i.e., from equations (8) and (9),

$$\begin{aligned}(E_b - E_0) - I_{ao}(R + R_0) &= I_a . Z \\ &= (I_{ao} - I_{\text{min.}}) . Z\end{aligned}$$

$$\therefore \quad I_{a0}\{Z + R + R_0\} = I_{\text{min.}} Z + E_b - E_0$$

$$\therefore \quad I_{ao} = \frac{I_{\text{min.}} Z + (E_b - E_0)}{Z + (R + R_0)} \quad .. \quad (11)$$

Proof of Graphical Construction.

Referring to the diagram of Fig. 3, we had

$$\begin{aligned}HO &= \sqrt{(R + R_0)^2 + \omega^2 L^2} = Z \\ HB &= E_b - E_0 \\ OM &= R + R_0 \\ MA &= I_{\text{min.}}(R + R_0)\end{aligned}$$

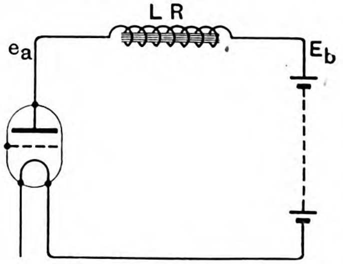


Fig. 4.—*Anode circuit of L.F. choke amplifier.*

From the properties of similar triangles,

$$\frac{AD}{CD} = \frac{HB - MA}{HM}$$

$$\begin{aligned}\therefore (MD - MA) . HM &= (HB - MA) . CD \\ \therefore MD . HM &= MA(HM - CD) + HB . CD \\ &= MA . HO + HB . OM\end{aligned}$$

$$\therefore \quad \frac{MD}{OM} = \frac{\frac{MA . HO}{OM} + HB}{HM} = \frac{I_{\text{min.}} Z + (E_b - E_0)}{Z + (R + R_0)}$$

Therefore, from equation (11), $\frac{MD}{OM}$ must represent I_{ao}, and hence the line OD represents I_{ao}.

Whence, again, since $I_{ao} - I_{\text{min.}} = I_a$,

$$AD = MD - MA = I_a(R + R_0)$$

and further

$$GF = \frac{ON}{OM} . AD = \frac{z}{R + R_0} . AD$$
$$= I_a z,$$

thus proving the construction.

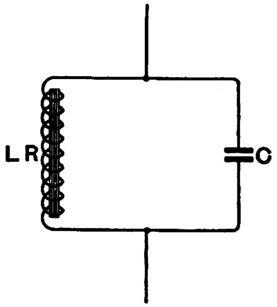


Fig. 5.

Finally, since $\frac{BK}{HO} = \frac{AD}{OM} = \frac{GF}{ON}$,

$$\therefore \quad BK = \frac{ZI_a z}{z}$$
$$= \mu_0 E_g \text{ by equation (9).}$$
$$= - \mu_0 E_{g0}.$$

It may be interesting to note that, if L be put equal to zero in equation (11), the expression reduces to the equivalent for a resistance amplifier, for which case, since Z reduces to $R + R_0$,

$$I_{ao} = \frac{I_{\text{min.}}(R + R_0) + (E_b - E_0)}{2(R + R_0)}$$
$$= \tfrac{1}{2}\left\{\frac{E_b - E_0}{R + R_0} + I_{\text{min.}}\right\}$$

or, since $I_a = I_{ao} - I_{\text{min.}}$,

$$I_a = \tfrac{1}{2}\left\{\frac{E_b - E_0}{R + R_0} - I_{\text{min.}}\right\}.$$

In conclusion, it should be pointed out that the above analysis for a simple choke is capable of considerable extension to include more complex circuits. If, for example, we have to take account of a shunting capacity, C, as in Fig. 5, we may substitute throughout for z the quantity z', where

$$z' = \frac{z}{\sqrt{1 - 2\omega^2 CL + \omega^2 C^2 z^2}}$$

while ϕ will now represent the angle $\tan^{-1} \frac{\omega L - \omega C z^2}{R}$. z' is, of course, the ohmic impedance of the combination of Fig. 5 to the given frequency, and a convenient graphical method of obtaining its value has already been described in a former issue of this journal* It is therefore possible to substitute for ωL and R in the lower portion of Fig. 3 the equivalent series values of reactance and resistance for the combination, which may be rapidly ascertained from the Impedance Diagrams referred to. The subsequent procedure and analysis are unaltered, provided the new significance of ωL and R is kept in view.

The gradient of the slope line VW will, of course, still be that corresponding to the D.C. resistance of the coil, and not the "equivalent" resistance of the combination.

APPENDIX I.

To Inscribe the Ellipse in the Given Rectangle

It will be sufficient to find the four points P, Q, S, T at which the ellipse touches the circumscribed rectangle (Fig. 3).

When $\frac{di_a}{de_a} = 0$, *i.e.*, when $i_a = \pm I_a$, we have from equation (4)

$$(e_a \pm I_a z \cos \phi)^2 = 0$$

i.e., $$e_a = \mp I_a z \cos \phi = \mp I_a R.$$

If P and Q be the two points where $\frac{di_a}{de_a} = 0$, the gradient of PQ is $- \frac{I_a}{I_a R} = - \frac{1}{R}$. Also W lies on PQ.

Hence the line VW of gradient $- \frac{1}{R}$ meets the upper and lower sides in P and Q.

Again, when $\frac{di_a}{de_a} = \infty$, *i.e.*, when $e_a = \pm I_a z$, we have from equation (4)

$$(\pm I_a z + i_a z \cos \phi)^2 = z^2 \sin^2 \phi \, (I_a^2 - i_a^2)$$

i.e., $$I_a^2 \cos^2 \phi \pm 2 i_a I_a \cos \phi + i_a^2 = 0$$

i.e., $$i_a = \mp I_a \cos \phi.$$

---

* See W. A. Barclay: "Some New Coil Impedance Diagrams," *E.W. & W.E.*, Feb., 1927.

If S be the point $(-I_a z, I_a \cos\phi)$, since P is $(-I_a R, I_a)$

$$\text{Gradient of } PS = \frac{I_a - I_a\cos\phi}{-I_a R + I_a z} = \frac{I_a - I_a\cos\phi}{-I_a z\cos\phi + I_a z}$$

$$= \frac{1}{z}, \text{ the gradient of the diagonal.}$$

$$\text{Also, Gradient of } QT = \frac{1}{z}.$$

Therefore, the points S and T are found by drawing through P and Q parallels to a diagonal to meet the vertical sides.

By using these four points of contact, and the fact that the characteristic $e_g = 0$ provides an additional tangent, the ellipse may be rapidly sketched in.

APPENDIX II.

SYMBOLS EMPLOYED.

e_a = instantaneous voltage on anode.
e_g = instantaneous voltage on grid.
i_a = instantaneous anode current.
E_a = amplitude of varying component of e_a.
E_g = amplitude of varying component of e_g.
I_a = amplitude of varying component of i_a.
E_{a0} = steady or normal component of e_a.
E_{g0} = steady or normal component of e_g.
I_{a0} = steady or normal component of i_a.
E_b = H.T. battery voltage.
$I_{\text{min.}}$ = minimum permissible value of i_a for valve.
μ_0 = amplification factor of valve.
E_0 = " space charge voltage effect " of valve.
R_0 = anode A.C. resistance of valve.
R = resistance of choke.
L = inductance of choke.
z = impedance of choke at frequency $\frac{\omega}{2\pi}$.
Z = impedance of choke and valve at frequency $\frac{\omega}{2\pi}$.
z' = impedance of choke and shunt capacity C at frequency $\frac{\omega}{2\pi}$.
$\phi = \tan^{-1}\frac{\omega L}{R}$.

The Washington International Radiotelegraphic Convention of 1927.

I. E. E. Wireless Section Chairman's Inaugural Address.

Abstract.

THE opening meeting for the session of the Wireless Section of the Institution of Electrical Engineers was held on Wednesday, 7th November, when the chair was taken by the Institution President, Col. K. Edgcumbe.

On the motion of Capt. P. P. Eckersley, seconded by Capt. Kennedy-Purvis, a vote of thanks to the retiring chairman (Lt.-Col. A. G. Lee, O.B.E., M.C.) was carried with acclamation.

The new Section Chairman, Commander J. A. Slee, then delivered his inaugural address, which was on the subject of the 1927 International Radiotelegraphic Convention of Washington.

Historical.

The new chairman opened his address by tracing the history leading up to the 1927 Convention.

In the infancy of wireless there were practically no rules—national or international. The Government did not assume control of wireless until 1904 The development of marine work had, however shown the necessity for some international agreement, especially with regard to questions of the safety of life at sea. As a result, a meeting was summoned in Berlin in 1903, the main work of which was to prepare proposals for a subsequent assembly, which was the International Radiotelegraphic Conference of Berlin, held in 1906. Perhaps the most striking decision reached was the abolition of the " no-intercommunication " principle, thus acknowledging wireless to be a universal, as opposed to a private, means of communication between the inhabitants of the world.

The meeting of 1906 was followed by the Conference of 1912 in London, at which was produced the document known as the Radiotelegraphic Convention of London, 1912. This continued the work of the 1906 meeting, and was concerned almost exclusively with ship work and with " spark signalling." With the exception of Poldhu very little progress had been made in long-distance communication or in point-to-point working. The arrangements then made have formed the basis on which all ship work is still carried out. The original object of installing wireless in ships was to earn a revenue, and the methods then fixed of conducting the truly international accounts—for ships and coast stations of all nations take part in this service—remain almost without alteration to this day.

It was then decided also that conferences should be held at five-year intervals, and that the next meeting should be at Washington in 1917. This was, of course, prevented by the war, and wireless arrangements could only exist between allies.

During the war the technical development of wireless was remarkable, the advent of the three-electrode valve revolutionising both transmission and reception. The effect of these enormous strides was felt in the warlike organisation of the time, and elaborate inter-allied agreements were worked out and made use of during hostilities.

After the war, in addition to the difficulties of rearranging the old Convention so as to bring it into line with the vast technical improvements made in the interval, there remained the diplomatic problem of getting the nations to meet in friendly discussion on so thorny a subject. Technical improvements had given stations a world-wide range and world-wide powers of interference, so that there was every prospect of acute differences arising between rival claimants for the wavelengths necessary to carry on the wireless communications of the world.

In 1923 an inter-allied commission met at Washington to work out some document which could be circulated to the world as a basis of truly international discussion. This meeting used the old wartime interallied agreement as a foundation, and in due course circulated the result of its labours with an invitation to all nations to attend an International Conference as soon as it could be arranged.

National rejoinders were forwarded to Washington with all the remarks, counter proposals and explanations of the 74 States likely to be represented. These were printed together, and circulated for further discussion. During this time the complexity of the subject had been added to by the rapid growth of broadcasting and the enormous weight of public opinion which it carried. The old professional wireless services—Naval, Military, Air Force, Post Office, and Commercial—found themselves being elbowed out of the ether by the demands of this vigorous new claimant for a share in the available wavelengths.

As a final complication came the reintroduction of short waves and the beam system which only proved itself to be a practical proposition a few months before the Washington Conference assembled.

The Washington Meeting of 1927.

The Conference, as finally assembled at Washington in 1927, consisted of some 400 delegates from 74 Governments, speaking 52 languages. The subject to be discussed had changed out of all recognition since the last fully international meeting, while the administrative side of the proposals opened up a wide cleavage of view due to the differences between the constitutional powers of the U.S.A. and the powers of most European states.

The Conference, consisting only of official delegates from the various countries, met and drew up rules of working, dividing the work into sections under eleven committees. The representatives of wireless companies and other wireless interests, who had been invited to be present, could attend the main and committee meetings, and address the meetings by permission of the chairman, but had no voting powers.

The great changes which had taken place in the subject made the distribution of work difficult. This was frequently solved either by handing over parts of the work from one committee to another, or by joint meetings of two or more committees. These formal committees split up into less formal sub-committees which were in many cases further divided. This fine distribution of work made it necessary for each of the maritime countries to be represented simultaneously in several different rooms, and the daily working hours of all members of the delegates became very long.

The language difficulty was settled as follows: Volunteers from among the delegates and the representatives of private companies were appointed as "Rapporteurs" to the various committees and sub-committees, to act as secretary and interpreter. The official language was French, and any delegate who so wished might ask for a translation into English, while any speech made in English was translated into French as a matter of routine. The drafts of all minutes were agreed at the next meeting and handed by the "Rapporteur" to the Drafting Committee. In the smaller and less formal meetings, the chairman usually did any necessary interpreting.

Work was carried out in this way for about six weeks, when began the period of sub-committees reporting to committees and of committees reporting to plenary sessions. Progress at this period was rapid, as the discussions had all taken place outside and agreement had already been reached. The only details requiring careful scrutiny were the exact draftings of paragraphs which embodied the work of two or more committees. Special care was necessary in the wording of administrative regulations, so that the largest possible number should be acceptable as they stood to the U.S. and other countries whose constitutional position differed from that of most European states. A very small portion of such regulations was left in an appendix which a few governments were unable to sign, due to legal inability to undertake the enforcement of regulations which were outside their constitutional powers.

Throughout all the preliminary discussions and during the Conference itself, the Government officials had at their disposal the services of the commercial representatives; indeed, in some cases, nations had to delegate temporarily the national voice to a commercial representative in order that enough people might be available to attend the large number of simultaneous sub-committees.

The 1927 Convention.

The Convention itself consists of 24 Articles, couched in the broadest terms, in which the governments concerned bind themselves to work together to enforce the regulations and to repress illicit work. It also sets up the principle of arbitration in case of disagreement and re-states the former principles of priority for distress messages from ships and of general intercommunication between ships.

Then follow the regulations which are enforced under the Convention—34 in all as now printed.

The technical side of the regulations is based on the idea that there are certain services carried out by stations distinguished by the corresponding name and that types of emission shall be classified and their uses controlled according to this classification. The wireless services are " Fixed," " Mobile," " Broadcasting," and " Special," which includes Time Signals, Direction Finding, Standard Waves, etc. A generous allocation of the shorter waves is also made to amateurs for experimental purposes.

Waves are divided into four classes—A1, A2, A3, and B, which may be interpreted as Continuous Waves, Interrupted Continuous Waves, Telephony and Spark. The article on this subject (article 5) lays down the wavelengths to be used for the various services and goes as far as possible in the direction of discouraging the use of spark. All of the different interests gladly accepted this article as a workable basis on which the wireless work of the world could be carried out, providing a certain amount of flexibility so that future contingencies might be met without summoning a special conference.

The Convention agreed to the introduction of the practice of designating waves by their frequencies in kilocycles per second, but no very great progress has yet been made in this direction. The distribution of waves among the different services was a matter of difficulty, but by the time the proposals reached the Technical Committee there was not a single dissentient voice.

As regards fixed services, the position is simple. As a general principle, one wave is allotted to one station. The Administration is responsible that suitable waves are allotted, and once a station is granted a licence to work on a certain wave the station is free to make the best use it can of the privilege.

With mobile stations the case is different. There are about 12,000 ships, which must be able to get into touch with one another or with land. The operators must be up to a high standard of competence and apparatus must be kept up to a definite state of efficiency. There must be an international code of signalling and procedure and accounts to be rendered in many languages and using many currencies, must be standardised in form. The ship service must be regulated so as to provide the best touch between ship-and-ship, and ship-and-shore, both for safety of life at sea and for the commercial convenience of the great liners. All the regulations governing these complex matters must be truly international in character, clear, binding and yet flexible enough to permit of unforeseen contingencies being encountered and satisfactorily dealt with.

The regulations for aircraft are similar in principle to those for the control of ship working. So far there is no regular exploitation of commercial communications to and from aircraft, but no doubt these will come into being when long-distance flights become frequent.

After the regulations proper appear numerous appendices which support the regulations in a more detailed fashion, including the list of authorised abbreviations now well known over the seven seas.

Finally, the book is completed by the additional regulations (seven in number) dealing with details of accountancy, which, as already mentioned, certain states were unable to sign.

Conclusion.

Taking a broad view of the whole Convention, it should have the effect of regularising existing practices without fixing them so firmly that progress will be impeded. So far as possible progress will be accelerated in the direction of the reduction of the interference caused by ships. There will be a general reduction in interference due to the more scientific use of the means of communication now available. Above all, the foundations have now been firmly laid for a series of similar international meetings at which there will be less to be done at one blow and fewer conflicting requirements to be satisfied, and from which real improvements in the international wireless arrangements can be looked for with confidence.

At the conclusion of his address, a vote of thanks to the new chairman was carried with acclamation on the motion of the Institution President.

A Double Super-heterodyne.

A Description of a Receiver built by the Author.

By J. F. Ramsay.

THE merits of supersonic amplification for particular purposes are well established. As a means of obtaining extreme sensitivity the super-heterodyne is unsurpassed. It is strikingly successful in overcoming the difficulties of amplifying the higher radio frequencies. The benefits of having a local oscillating valve, the output of which can be controlled, are made good use of. Opprobrium has been cast, and to some extent justifiably, on the quality of reproduction of the super-heterodyne. Here we are concerned with policy. So much emphasis has been given to the "distance-getting" properties of the super-heterodyne that manufacturers feel it incumbent upon them to secure a maximum gain per stage; they use sharply tuned couplings and high *m* valves. Quality is not a feature of such an arrangement. The conditions for (1) maximum voltage amplification and (2) maximum distortionless A.C. output are wholly different —valves have yet to be made which give both of those requirements together. At present we can only effect a compromise.

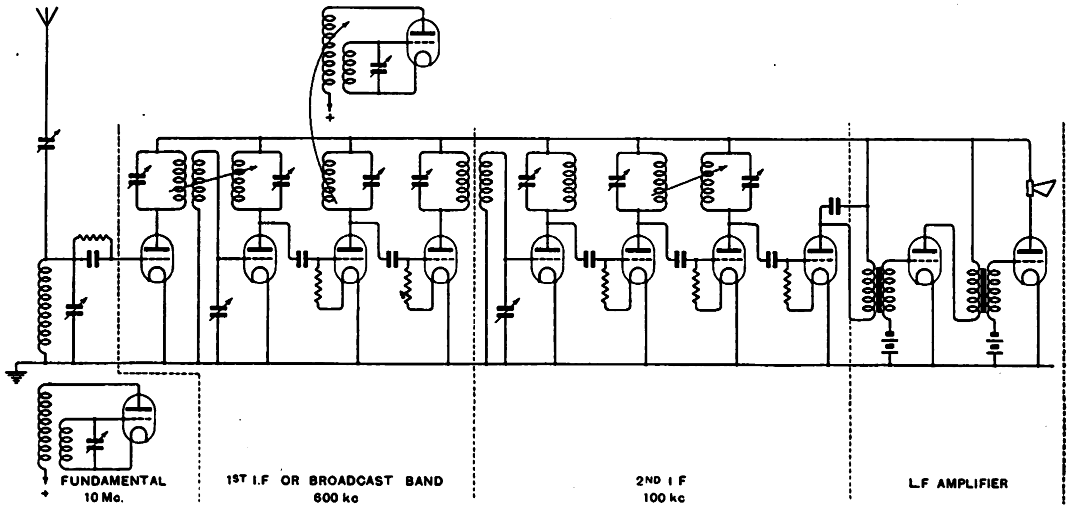


Fig. 1.—*Circuit of the double super-heterodyne.*

The super-heterodyne is not popular in this country—ask any wireless salesman—but the precise psychological reasons for this are beyond us. The evil reputation associated with "quality" may have something to do with it; it need not. Moreover, we are well supplied with broadcast stations and, being as a nation conservative, we accede to the cry of the B.B.C. to cultivate the local station, and are satisfied. He who shouts convinces. This is most regrettable, as it has prevented a wider appreciation of a most excellent receiver.

Many articles have appeared on super-heterodynes, but we have not seen any practical details of that extension of the system which may be called "multiple heterodyning." This is an old idea and may be outlined as follows: If a valve oscillator is coupled to a circuit which is tuned to a particular signal frequency, "beating" is obtained, the nature of the beats being determined by the initial conditions—*i.e.*, the frequency of the local oscillation and the relative amplitudes of the interfering oscillations. (We here propose to talk of "frequency" and "amplitude" of a beat, although rigorously, this is erroneous). The frequency of the beat, for the purposes we are concerned with, is equal to the difference in frequency between the signal and local oscillatory currents. The success of the super-heterodyne is due to the fact that the beat frequency is such that it lies in the range 10-300 kilocycles. Amplifiers operating in this band can be designed to give a reasonable efficiency. Cascading may be resorted to with more or less impunity. Having amplified the beat we can now introduce a second local oscillation such that it beats with the first beat. Hence we obtain a second beat of still lower frequency. This may now be amplified successfully.

A third local oscillation is then introduced, and further amplification undertaken; and so on.

However, in the set shown in the accompanying photographs, heterodyning is only carried out twice. Although the technical difficulties may seem formidable, in actual practice comparatively little trouble is experienced; some care has to be taken with the preliminary adjustments and the strength of the local oscillations.

The receiver comprises fundamental, two heterodynes and, correspondingly, two supersonic amplifiers, these amplifiers operating on different frequencies.

Circuit Details.

The input E.M.F. (the signal) is applied to grid and filament of a "frequency changer," to which is coupled an oscillator giving a beat of about 600 kc. This is amplified by two valves, tuned-anode-coupled, and the magnified E.M.F. applied to a second frequency changer, to which a local oscillator is coupled, and a beat of about 150 kc. obtained. This is passed through a three-stage radio-frequency amplifier (tuned anode), rectified and amplified by a two-stage low-frequency amplifier.

Fig. 2 is the front view, showing controls and switches. For short-wave reception (using the entire apparatus) only the two large vernier dials on the left are used. In the case of short-wave C.W., the second intermediate frequency amplifier is made to

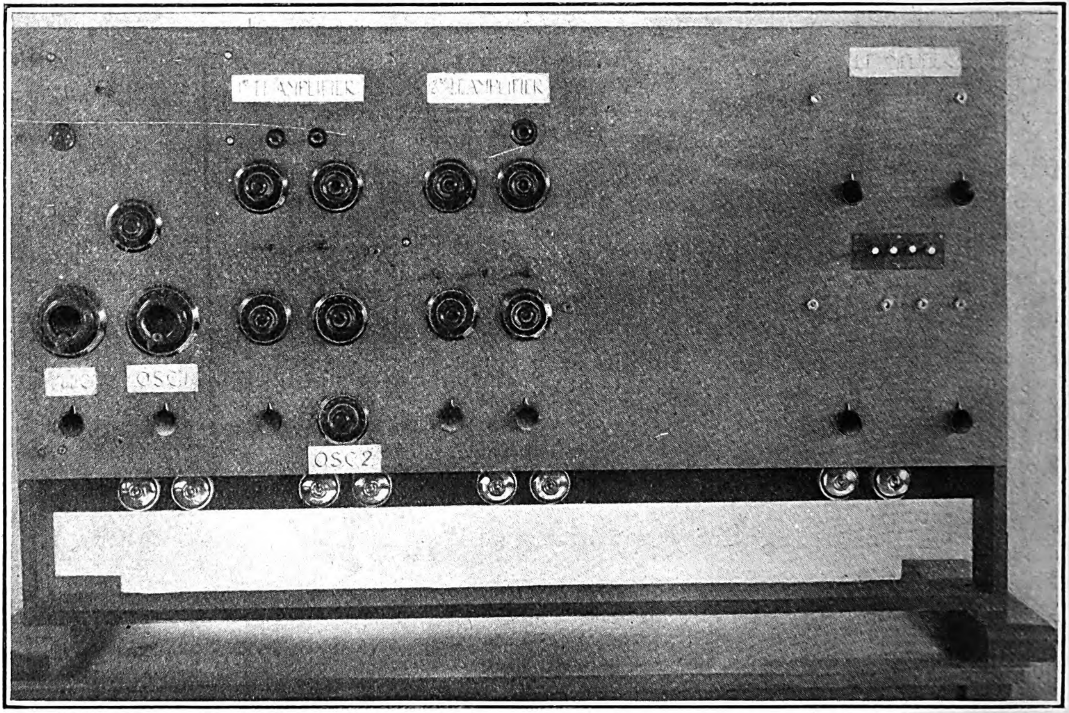


Fig. 2.—*Tuning controls and switches.*

oscillate by increasing the coupling between the last two tuned-anode coils.

Fig. 3 is a complete back-of-panel view, including coils and valves.

Fig. 4 shows the fundamental "detector," local oscillator, 1st I.F. amplifier, and 2nd oscillator.

Fig. 5 shows the first I.F. amplifier, second oscillator, and second I.F. amplifier.

Fig. 6 shows the L.F. amplifier, two-stage transformer-coupled. Above this amplifier is an auxiliary two-valve resistance-coupled amplifier; this is a freak amplifier and makes use of the secondary emission effect of a screened-grid valve.

Amplifiers to operate on a single frequency were not favoured since (1) it is a distinct advantage to be able to change the supersonic frequency, and (2) it was desired to use the amplifiers as straight receivers covering specific bands of frequencies. The stages had therefore to be tuned.

The frequency ranges of the amplifiers were governed by the following considerations. The first amplifier was intended to be used as a straight broadcast receiver (500-1,000 kc.), the output being either put into the L.F. amplifier, or into the second I.F. amplifier; in the latter case an oscillator is of course switched on. This arrangement (a single oscillator super-heterodyne) constitutes an exceedingly powerful broadcast receiver and embodies ten valves.

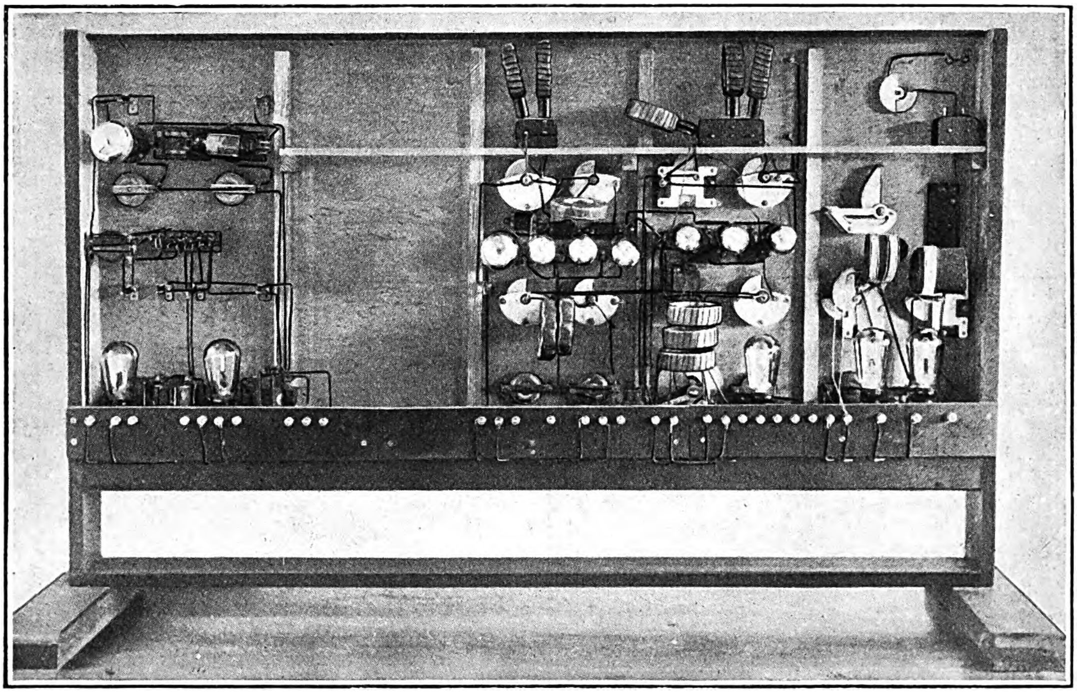


Fig. 3.—*Complete back-of-panel view.*

It will be seen that no attempt at screening has been undertaken. Although an advantage, it has been found to be unnecessary; the apparatus is sufficiently stable, and if beating between the oscillators does occur the intermediate frequencies may be altered.

The justification for a set of this nature is interesting. First, it was desired to have a maximum sensitivity, necessitating the use of a fair number of valves.

Secondly, the receiver was to be useful over as large a frequency range as possible.

Again, the second I.F. amplifier was for use as a straight receiver on the longer broadcast wavelengths; the frequency range is therefore 100-300 kc.

The fundamental panel comprises simply a detector (or frequency changer) and an oscillator, the tuning range being approximately 30-50 m.

Thus we start, say, with a signal on 45

metres, change to about 500 metres, and change again to about 2,000 metres.

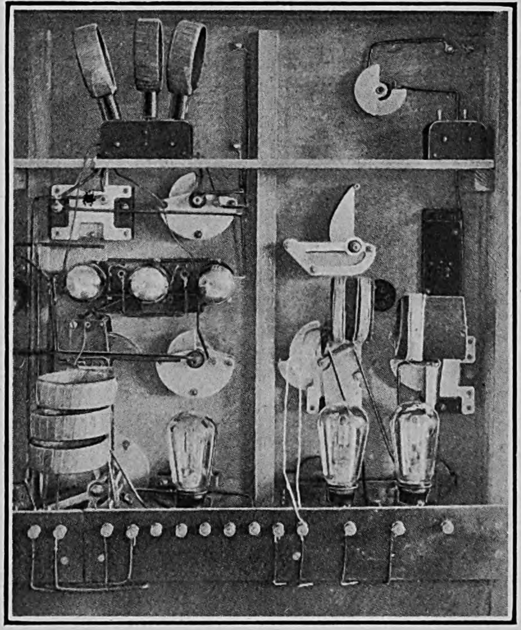


Fig. 4.—*Fundamental and 1st I.F. panels.*

As would be expected, remarkable results are obtainable. Using the single-stage super-heterodyne (ten valves) broadcast from all over Europe can be put on the loud speaker without the use of an aerial. With an aerial continental broadcast is received at excellent strength on the loud speaker, using only one L.F. stage, the quality being exceedingly satisfactory.

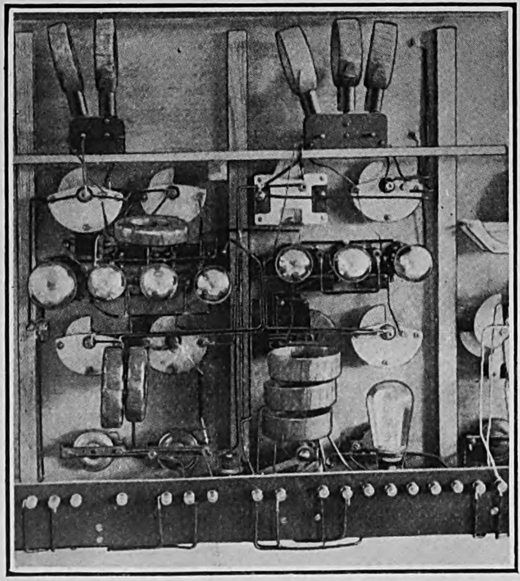


Fig. 5.—*1st I.F. amplifier, 2nd oscillator, 2nd I.F. amplifier.*

The double super-heterodyne is even more sensitive. It is possible to tune in low-power amateur C.W. by its ripple alone; amateur telephony can be picked up without preliminary oscillation. Broadcast from Schenectady, New York, can be made to overload the loud speaker; it has been received without an aerial, but was barely intelligible.

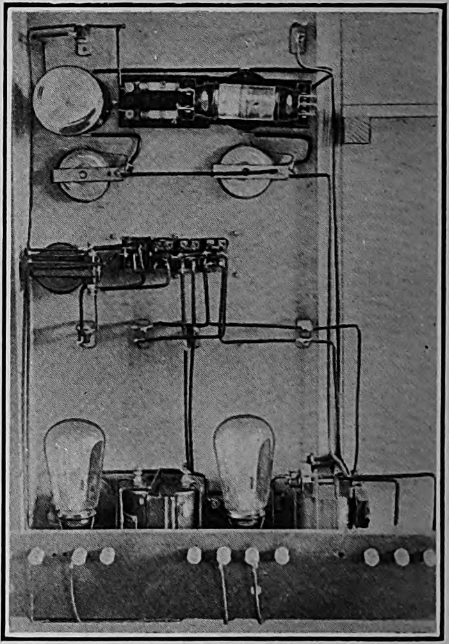


Fig. 6.—*L.F. amplifiers.*

As far as the set itself is concerned, the great number of variables certainly conduce to complexity but considerably enhance the experimental elasticity, which is sufficient justification. To one initiated operating is indeed delightful by virtue of the control of amplification, and by the fact that new features are continually revealing themselves. In effect, in the opinion of the writer, it may be said with some justification that such a receiver is a close approximation to the ideal.

A Note on Some Interfering Oscillations Experienced in a Supersonic-Heterodyne Receiver.

By R. L. Smith-Rose, D.Sc., Ph.D., A.M.I.E.E.

A TYPICAL arrangement of a supersonic-heterodyne receiver for the reception of continuous-wave signals is shown in the schematic diagram, Fig. 1. The arriving waves produce oscillations of a frequency f_1 in the aerial receiving circuit. By adding to these oscillations of a frequency f_2 obtained from the first local oscillator and rectifying the combination, a set of oscillations having a frequency $f_3 = f_1 \sim f_2$ is obtained. The value of f_3 may be in the suitably low radio-frequency band within which large magnification may be obtained in the intermediate-frequency amplifier. During the course of this amplification another set of oscillations of frequency f_4 is introduced from the second local oscillator. The output from the second detector will then consist of oscillations of a frequency $f_5 = f_3 \sim f_4$. If f_5 is within the audio-frequency range, these oscillations will thus produce a response in a pair of telephone receivers, either before or after passage through a suitable audio-frequency amplifier. In this manner the incoming continuous-wave signals at a frequency f_1 may be made to produce a response in the telephone receivers or to operate a suitable recorder from the audio-frequency currents finally obtained.

In practical operation the frequency f_3 will naturally be chosen to suit the intermediate-frequency amplifier, which may be made highly selective and very efficient at this frequency. The frequency of the first oscillator will therefore be determined by the frequency of the incoming signals to satisfy the equation $f_3 = f_1 \sim f_2$. The second local oscillator is obviously required to work at a frequency in the neighbourhood of that of the intermediate-frequency f_3, since f_3 and f_4 only differ by an audible frequency. Incidentally, it is thus seen that the pitch of the note heard in the telephones is easily adjustable to the best value by altering the second local oscillator. Once the best adjustment of this oscillator is obtained, no alteration is required with change of wavelength of the incoming signals, since the intermediate-frequency oscillations are obtained by adjusting only the receiving circuit and the first oscillator. It is this simplicity of control which comprises one of the greatest advantages of the supersonic-heterodyne type of receiver. Although the intermediate-frequency amplifier may contain several stages of sharply-tuned circuits, the resulting high selectivity is available for use over a large range of received wavelengths merely by tuning the receiving circuit * and the first oscillator.

The processes described above will perhaps become clearer if some typical figures are allocated to the various frequencies. Suppose that the arriving signals are on a wavelength of 100 metres, corresponding to a frequency of 3,000,000 cycles per second. Then by setting the first oscillator to a frequency of 2,900,000 cycles per second, an intermediate-frequency of 100,000 is obtained, i.e., corresponding to a wavelength of 3,000 metres. If now the second local oscillator is set to a frequency of 99,000 cycles per second, a steady note of pitch 1,000 cycles per second will be produced in the telephones. If the wavelength of the signals is changed to 150 metres, i.e., a frequency of 2,000,000, then by altering the first oscillator frequency to 1,900,000 the same intermediate frequency of 100,000 cycles per second will result, and the signals will be heard at the same pitch in the telephones without any alteration of the second oscillator.

During the development of a highly sensitive supersonic-heterodyne amplifier for the reception of continuous-wave signals, the writer has had cause to trace out the source of various interfering oscillations arising in the receiver. It is thought that a brief description of the nature of these oscillations and the methods of eliminating them may be of interest.

*** In some cases for the reception of very short wave signals, even this tuning adjustment may be dispensed with.**

In the first place, either of the two local oscillators employed in the receiver may not be producing continuous oscillations. It is well known that a valve oscillator containing a grid leak and condenser combination may produce an interrupted type of oscillation. The process of interruption, which has become commonly known among wireless engineers as "squegging," is due to the accumulation of a negative charge on the grid of the valve during oscillation. On reaching a sufficiently high value this negative charge on the grid decreases the anode current below the point necessary for the maintenance of oscillation. The presence of the grid leak permits the charge to leak away slowly to the point at which the oscillations are restarted, and the process is then repeated. The period of the interruption is evidently determined by the magnitude of the grid condenser and leak, and by the valve constants. If the first oscillator valve is "squegging" at an audible frequency the interruption will be superimposed upon the intermediate-frequency oscillations upon the arrival of signals which will thus become audible after passing the second detector without the aid of the second oscillator. This may prove to be a convenient method of receiving continuous-wave signals, but it is usually desirable to put a stop to the "squegging" process. The desirability of this will be the more appreciated when it is pointed out that the frequency of interruption may be above the audible range, and may for example be within the working range of the intermediate frequency amplifier. In this case its presence will be indicated by switching on the second oscillator when a steady howl is produced in the telephones at a pitch which is independent of the adjustments of the receiving circuit and first oscillator. By a suitable choice of the values of the components used in the construction of the valve oscillators, it is not difficult to secure steady oscillations free from the interruption described above. From a limited experience with different types of superheterodyne receiver it appears that the liability to "squegging" is greater when one valve is made to serve the dual purpose of first oscillator and first detector, a practice which is adopted in some manufactured types of receiver, but which has little to recommend it save the doubtful point of valve economy.

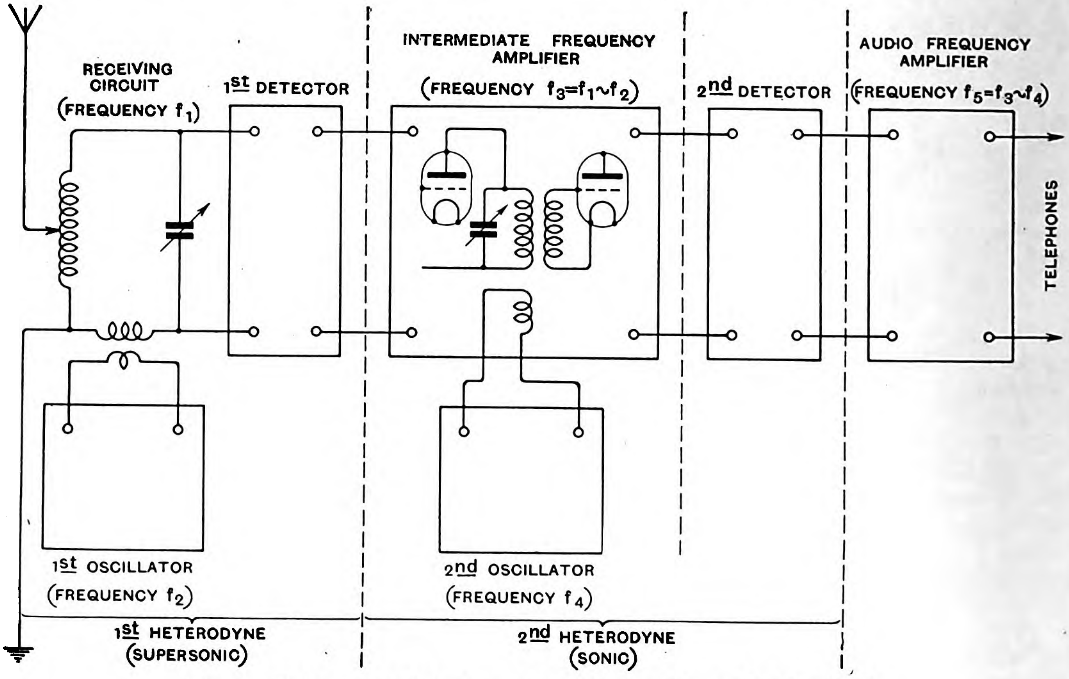

RECEIVING CIRCUIT (FREQUENCY f1)
1st DETECTOR
INTERMEDIATE FREQUENCY AMPLIFIER (FREQUENCY f3=f1∿f2)
2nd DETECTOR
AUDIO FREQUENCY AMPLIFIER (FREQUENCY f5=f3∿f4)
TELEPHONES
1st OSCILLATOR (FREQUENCY f2)
2nd OSCILLATOR (FREQUENCY f4)
1st HETERODYNE (SUPERSONIC)
2nd HETERODYNE (SONIC)

Fig. 1.—*Typical superheterodyne circuit for reception of C.W. signals.*

The second source of disturbance in a receiver of the type under discussion arises from the self-oscillation of the intermediate frequency amplifier either as a whole or in individual stages. Since this amplifier is intentionally made very selective, as it is required to operate over only a narrow band of frequencies, the oscillations will take place at a frequency in the neighbourhood of f_3 (see Fig. 1). They will thus be suitable for heterodyning the incoming signals, which will immediately become audible on tuning the first oscillator, with the second oscillator shut off or disconnected from the circuit. Alternatively, with the first oscillator shut off so that incoming signals do not produce any currents at the intermediate frequency, these oscillations may be detected by switching on and adjusting the second oscillator when a steady audible beat note will be obtained. In some cases, particularly as an emergency measure, this use of the intermediate frequency amplifier in the oscillating condition renders the reception of short-wave C.W. signals possible without the necessary provision of a second oscillator. But since little or no control is obtained over the amplifier when it is oscillating, the optimum heterodyne condition cannot be obtained by adjusting the amplitude of the local oscillations, and an oscillating receiver is liable to become very noisy. For the highest efficiency it is desirable to stop the generation of oscillations in the intermediate frequency amplifier, either by the use of positive grid bias or by a neutrodyne or other anti-reaction control.

The third cause of interfering oscillations in a superheterodyne receiver is a little more elusive than the two just dealt with, since its presence only becomes evident when the whole of the receiver is in operation. This disturbance is encountered as a steady musical beat note, the strength and pitch of which depends upon the adjustments of both oscillators and also on the tuning of the receiving circuit. In brief, this spurious oscillation has every appearance of being due to a steady incoming continuous wave signal such as the carrier wave of a broadcasting station. The scheme of connections of the receiver in which this was discovered is shown in Fig. 2. A frame aerial was employed in the primary receiving circuit, which was completed through the coupling inductance coil L_1 and the variable tuning condenser C_1. The first set of local oscillations was introduced into the secondary circuit L_2C_2, which was connected to the first detector and the intermediate-frequency amplifier at a suitable point, of which the second set of local oscillations was introduced. For the reception of modulated signals, such as broadcasting transmissions, the second oscillator is not required, and may be switched off. In this condition the set was found to give perfectly satisfactory reception on all wavelengths. By adjustment of the control provided on the intermediate-frequency amplifier this could be made to oscillate or not as desired, and it was found to be quite sensitive and satisfactory in the non-oscillating condition. When, however, the second oscillator was switched on for the reception of continuous wave signals, the existence of a steady oscillation became apparent on certain wavelength adjustments. The strength of the resulting signal heard in the telephones was found to be independent of the orientation of the frame coil, so that it was apparent that the oscillation was generated inside the receiver, and was not due to incoming waves. As a first explanation it was thought that the intermediate-frequency amplifier was being forced into oscillation by the second local oscillator; but this possibility was disposed of by making these local oscillations very weak and by increasing the stability of the ampli-

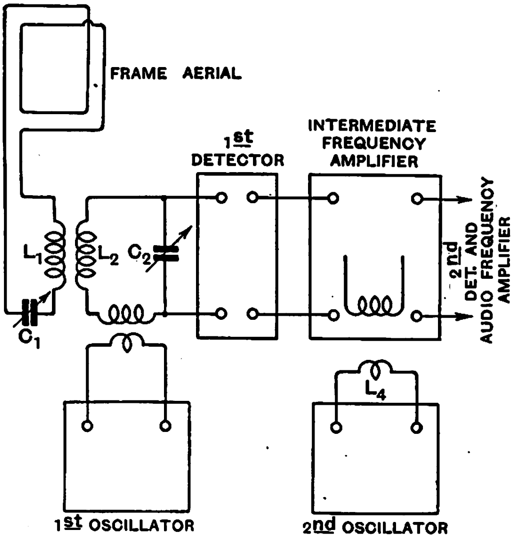

FRAME AERIAL
1st DETECTOR
INTERMEDIATE FREQUENCY AMPLIFIER
2nd DET. AND AUDIO FREQUENCY AMPLIFIER
L1
L2
C2
C1
L4
1st OSCILLATOR
2nd OSCILLATOR

Fig. 2.—*Scheme of connections in circuit employed.*

fier itself. It is also to be remembered that the interference was only experienced on certain wavelength adjustments of the primary and secondary receiving circuits.

The cause of the interference was brought to light by the discovery that two successive wavelengths upon which the disturbance was experienced bore a simple ratio to one another, and that the integers forming this ratio, when multiplied by their respective wavelengths, gave the same number, which was very approximately the wavelength at which the intermediate-frequency amplifier and the second oscillator were in operation. For instance, with the intermediate frequency corresponding to a wavelength of about 2,800 metres, interference was experienced at 467 and 400 metres, which are respectively the sixth and seventh harmonics of 2,800 metres. It would appear from this that the oscillations given by the second local oscillator were not pure, and that there was sufficient mutual inductance between its coupling coil L_4 and either the primary or secondary receiving circuit, or both, for a harmonic of these oscillations to be induced in these receiving circuits. When the two receiving circuits were set to the wavelength of this harmonic, a steady signal corresponding to it was transferred to the intermediate-frequency amplifier, and was subsequently made audible by being heterodyned by the fundamental oscillation of its own source—the second oscillator. Expressed in the nomenclature of Fig. 1, it will be evident that the condition for this interference to exist is that $f_1' = \frac{f_4}{N}$, where N is an integer indicating the order of the harmonic of the oscillation f_4, which caused the disturbance. Such an oscillation would have all the characteristics of an incoming signal, and could be sharply tuned on the primary and secondary receiving circuits. In the set in question, the whole of the receiver was carefully screened, so that the harmonic oscillation would not be induced into the frame coil. The strength of the resulting signal would not, therefore, vary with the rotation of this coil, and it was this fact alone which distinguished the disturbance from an incoming signal.

The validity of the above explanation was established by two very simple tests. First, by altering the adjustments of the intermediate frequency oscillator to give either a slightly higher or slightly lower frequency, the two wavelengths upon which the disturbance was experienced were shifted in the same sense, while their ratio remained constant. The second confirmation was obtained by searching for the positions of successive disturbing oscillations over the whole wavelength range of the receiver. In the upward direction this range was limited to about 600 metres, so that it was not possible to identify harmonics of a lower order than the fifth, which was located at about 560 metres. In the direction of shorter wavelengths the disturbing signals were picked out by careful search and accurate tuning down to 155 metres, which corresponds to the 18th harmonic of the second local oscillator. Over the range of the receiver—150 to 600 metres—there were thus fourteen different wavelengths upon which the harmonics of this oscillator caused a disturbance. The magnitude of the disturbance varied according to the strength of the particular harmonic concerned, but on most of the wavelengths it was found to interfere very seriously with all but the strongest incoming signals.

Having located the cause of the trouble, its removal or avoidance is a comparatively simple matter. As a temporary expedient in an emergency, it suffices to alter the wavelength of the second local oscillator so that its harmonic is removed from the working wavelength of the incoming signals. The most satisfactory plan, however, is to improve the quality of the oscillations concerned by fitting a suitable filter circuit to the second oscillator between its valve circuits and the output coil L_4. Alternatively, or as an additional precaution, the primary and secondary circuits of the receiver may be separately screened so that there is no mutual coupling between them and either the coil L_4 or the intermediate frequency amplifier.

The Effect of Frequency on the Value of High Resistances of the Grid Leak Type.

By W. Jackson, M.Sc.

THE usual type of grid leak or anode resistance may be regarded as consisting of a pure resistance R shunted by a small condenser C_0 representing the inherent self-capacity. The result of this small self-capacity is to produce a reduction in the effective resistance of the leak as the frequency increases, the effective resistance at a frequency $\omega/2\pi$ being given by the expression

$$R' = \frac{R}{1 + R^2 C_0^2 \omega^2}.$$

While C_0 will seldom exceed a few micro-microfarads, this reduction is very pronounced at frequencies approaching 10^6 cycles per second and explains the unsatisfactory voltage amplification of resistance-capacity-coupled amplifiers at high frequency.

It is of interest—if not of great importance for general purposes—to investigate whether there occurs any marked variation in the actual resistance R as the frequency changes, quite independent of the change in effective resistance R' due to self-capacity. The results of a series of measurements on several types of grid leak and anode resistance have served to show that such a variation in the value of R does actually occur and in some cases to a greater extent than would have been expected.

Method of Measurement.

The method of measurement consisted in an arrangement whereby the resistance under test could be connected across the terminals of a variable air condenser, which, along with an inductance, formed a simple tuned circuit loosely coupled to a valve oscillator capable of providing a wide range of frequency, and in measuring the resistance of the circuit with and without the leak connected. The connection of the leak across the condenser affects the circuit in two ways, namely, it produces a slight alteration in the required value of tuning capacity and a variation in the apparent high-frequency resistance. The self-capacity C_0 may be regarded as added directly to the main tuning capacity C and throughout the tests C was arranged to be sufficiently large to render C_0 negligible in comparison. The resistance R in parallel with C (Fig. 1) can be replaced so far as its effect on the circuit LC is concerned by an equivalent series resistance r, where ~ is given by the expression

$$r = \frac{1}{RC^2\omega^2}*.$$

Measurement of this change in circuit resistance on connecting the leak across the condenser C enabled the value of R to be determined over a considerable range of frequency. Any variation of R with frequency measured in this way will be quite independent of the shunting effect of its self-capacity C_0.

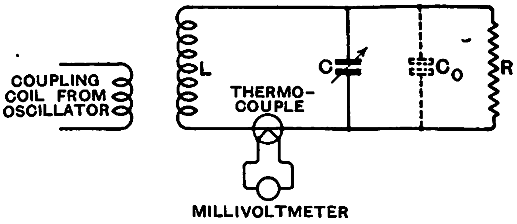


Fig. 1.

The resistance variation method, employing a thermocouple as current-measuring device, was adopted in determining the circuit resistance. Especial care was taken to retune the circuit by the small amount necessary on connecting the leak resistance across the variable condenser C. In order that at all frequencies the change in circuit resistance r produced by this connection was sufficiently large—compared with the resistance of the rest of the circuit—to ensure accuracy in its determination, it was necessary to employ in the tuned circuit, in turn, a number of coils of different inductance. The lower the frequency the larger the inductance of the coil used. The approximate inductances of the coils were: (*a*) 101 microhenrys, (*b*) 388 μH., (*c*) 2,133 μH., (*d*) 3,460 μH., (*e*) 5,099 μH., (*f*) 14,680 μH.

---

* See Appendix.

The self-capacity of the resistance *R* and holder was measured by noting the change in tuning capacity *C* on connecting *R* across the circuit. In all cases this was found to be about 2.0 micro-microfarads, for which the holder was mainly responsible.

The resistances tested were as follows:—0.25-megohm Dubilier; 0.25-megohm McMichael; 0.25-megohm Mullard; 0.1-megohm Mullard and a Lissen variable grid leak. The setting of the latter was, however, found to be unreliable, and a satisfactory set of readings was not obtainable. The direct-current resistance was measured by comparison with a standard resistance under applied pressures of from 4 to 20 volts, but little variation with voltage was noticeable.

Readings on 0.25-megohm Dubilier Grid Leak Resistance.

The usual type of Dubilier leak consists of a strip of compressed material impregnated with a black varnish and surrounded by a layer of wax, the whole being enclosed in a cylindrical casing of compressed paper. The type tested was of different pattern, the strip being surrounded merely by a glass enclosure.

Wave-length. (metres.)	Frequency in cycles per sec.	Circuit resistance without grid leak connected. (ohms.)	Circuit resistance with grid leak connected. (ohms.)	Change in circuit resistance. (ohms.)	Tuning capacity. ($\mu\mu$F.)	Resistance of grid leak.
6,890	$.435 \times 10^5$	77.50	145.20	67.70	910	.239 megohm.
4,320	$.694 \times 10^5$	50.15	71.20	21.05	1,029	.237 ,,
2,464	1.217×10^5	39.70	50.80	11.10	804	.238 ,,
1,120	2.680×10^5	8.31	9.73	1.42	1,022	.238 ,,
968	3.100×10^5	8.92	10.91	1.99	747	.238 ,,
806	3.720×10^5	9.73	12.70	2.97	502	.244 ,,
604	$4{,}960 \times 10^5$	11.36	17.12	5.76	271	.243 ,,
532	5.640×10^5	4.19	4.70	0.51	810	.238 ,,
441	6.810×10^5	4.37	5.13	0.76	554	.235 ,,
399	7.520×10^5	4.61	5.49	0.88	448	.251 ,,
355	8.460×10^5	4.71	5.85	1.14	354	.248 ,,
304	9.870×10^5	4.99	6.45	1.46	260	.263 ,,

Self-capacity of grid leak and holder = 1.60$\mu\mu$F.

D.C. Resistance.

Voltage applied.	4	8	12	16	20	Mean Resistance = .242 megohm.
Resistance.	.242	.243	.243	.242	.242	

Wheatstone's Bridge gave .247 megohm.

Readings on 0.25-megohm McMichael Grid Leak Resistance.

This resistance consisted of a short rod ($\frac{1}{8}$ inch diameter) of slate-coloured material, enclosed in an ebonite casing. Metal caps screwed into the ends of the casing made contact with the rod and formed the terminals of the resistance.

Similar readings were taken on the Mullard resistances which appeared essentially similar in construction to the usual type of Dubilier resistance except that instead of wax an air space separated the strip of resistance material and the outer paper casing.

The complete results are shown plotted in Fig. 2. The curves bring out two peculiar effects which may be stated as follows :—

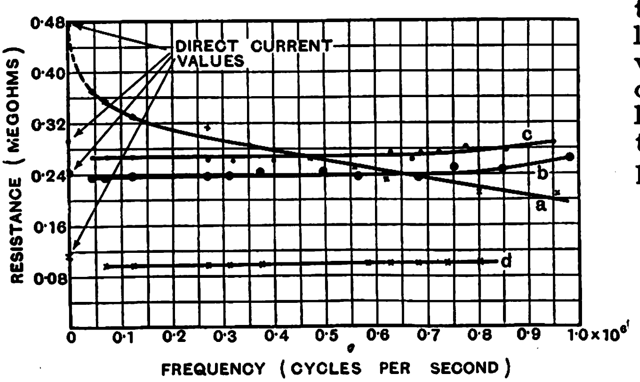


Fig. 2.—*a. McMichael, 0.25-megohm. b. Dubilier, 0.25-megohm. c. Mullard, 0.25-megohm. d. Mullard, 0.1-megohm.*

(1) The whole of the leak resistances tested appear, with decreasing frequency, to tend to a direct-current value lower than that given by the direct-current measurement. This is most marked in the case of the McMichael leak and is least noticeable with the glass-enclosed Dubilier.*

(2) While the Mullard and Dubilier leaks increase in resistance with frequency, the McMichael and Lissen variable leaks decrease, the McMichael falling very rapidly with increasing frequency. The Mullard and Dubilier leaks remain fairly constant until the frequency approaches 10^6 cycles per second.

Appendix.

$$\frac{1}{z}=\frac{1}{R}+\frac{1}{-j/C\omega}=\frac{1}{R}+jC\omega$$

$$=\frac{1+jRC\omega}{R}$$

where z is the symbolic impedance of R and C in parallel.

$$z=\frac{R(1-jRC\omega)}{1+R^2C^2\omega^2}=\frac{R}{1+R^2C^2\omega^2}-\frac{jR^2C\omega}{1+R^2C^2\omega^2}$$

Since $R^2C^2\omega^2$ throughout the previous measurements is large compared with unity

$$z=\frac{1}{RC^2\omega^2}-\frac{j}{C\omega}$$

giving an equivalent series resistance

$$r=\frac{1}{RC^2\omega^2}$$

Wave-length. (metres).	Frequency in cycles per sec.	Circuit resistance without grid leak connected. (ohms.)	Circuit resistance with grid leak connected. (ohms.)	Change in circuit resistance. (ohms.)	Tuning capacity. ($\mu\mu$F.)	Resistance of grid leak.
6,890	$.435\times10^5$	78.00	122.00	44.00	910	.368 megohm.
4,320	$.694\times10^5$	49.85	64.00	14.15	1,029	.352 ,,
2,464	1.217×10^5	39.70	47.70	8.00	804	.330 ,,
1,122	2.670×10^5	9.37	8.28	1.09	1,022	.314 ,,
845	3.550×10^5	9.64	11.91	2.27	296	.284 ,,
635	4.730×10^5	11.07	15.94	4.85	296	.266 ,,
535	5.610×10^5	4.34	4.82	0.48	822	.249 ,,
483	6.200×10^5	4.41	5.03	0.62	667	.232 ,,
376	7.980×10^5	4.64	5.81	1.17	400	.213 ,,
314	9.550×10^5	5.04	6.79	1.75	275	.208 ,,

Self-capacity of leak and holder = 1.90$\mu\mu$F.

D.C. RESISTANCE.

Volts applied.	4	8	12	16	20	Mean Resistance.
Resistance.	.479	.479	.477	.475	.475	= .477 megohm.

Wheatstone's Bridge gave .477 megohm.

---

* We do not think that the results as shown in Fig. 2 justify this conclusion.—EDITOR.

Correspondence.

Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Television.

To the Editor, E.W. & W.E.

SIR,—On page 239 of your issue of April, 1927, you published a contribution from M. Denes von Mihaly, wherein some exceedingly pertinent questions were asked as to the Baird system of "television."

I was recently favoured, at the Radio Exhibition, with a demonstration of this system, and those questions were brought back to my mind. As far as I can ascertain, Mr. Baird has never put forward any answer to M. Mihaly's statements, and it seems certain that some sort of reply is now more than ever imperative.

DUNCAN SINCLAIR.

Haynes Church End,
Bedfordshire.

Surges in Eliminator Smoothing Circuits.

To the Editor, E.W. & W.E.

SIR,—I have read with much interest Mr. A. G. Warren's article in the November number of *E.W. & W.E.* on "Surges in Eliminator Smoothing Circuits," but I would suggest that in many cases matters are not quite so bad as the analysis might lead one to believe, and that simple safety devices exist.

(*a*) The analysis given leaves out of account the resistance of the smoothing chokes; for small smoothing circuits (capable of supplying less than, say, 100 watts), the resistance of the choke is in practice rather large compared with the inductance; rough calculations on some figures given by manufacturers of commercial chokes show that the resistance has the effect of considerably reducing the maximum surge voltages occurring.

(*b*) Where the smoothing circuit follows a valve rectifier operating from A.C., two causes tend to reduce the surge voltage; first the rectifying valves will only pass a limited maximum current, which cause is always operative; and secondly, the rectifying valve filaments are usually substantial (*e.g.*, a B.T.H. "RH.1" takes 1½ amp. at 7½ volts), and therefore do not heat up instantaneously, hence for the first few thousandths of a second or so at least, the emission of the rectifier is low, and we get the effect of a gradual application of rectified D.C. voltage to the smoothing filter input, but this cause, which in practice seems to reduce surge voltages to very small amounts at switching on, would not be operative in the case of mains disturbance such as feeder switching causing a momentary interruption in supply.

(*c*) I am using B.T.H. B.12 output valves with filaments lighted from the same transformer which supplies the rectifier for H.T., the transformer primary being switched by relay from a distance; surge at break is not serious; due apparently to the output valves having thick filaments which do not become cold for an appreciable time, so that the valves remain conducting for long enough to prevent serious rise of voltage. I keep a "Ferranti" voltmeter with additional series resistance (making ½ megohm in all) connected permanently across the smoothing output condenser; on switching off the transformer primary, as described above, there is no visible upward movement of the pointer, it flicks *down* from, say, 425 to 350 or so in about ¼ to ½ second, and then drops at a much slower and, of course, gradually decreasing rate as the condensers discharge through the voltmeter resistance.

(*d*) *Safety devices.* It appears desirable to keep a high resistance of about ½ megohm always connected across smoothing circuit output, so as to discharge the condensers on switching off, otherwise well-insulated condensers will hold their charge for a long time, and there is risk of shock when making adjustments within even a minute or so after switching off. The voltmeter mentioned in (*c*) above performs this duty satisfactorily and indicates how soon it is safe to open the screening box and make adjustments (say when the reading has dropped to 100 or 50 volts, according to the operator's taste).

(*e*) *Surge Absorber.* There is a very simple safety device which does not seem to be sufficiently well known, and which is very simple and cheap to apply to any smoothing circuit dealing with less than, say, 100 watts. I refer to the Neon lamp. The "beehive" type, obtainable from the G.E.C. without any internal resistance, has an ignition voltage of about 149 volts, a sufficient number of these connected in series are bridged across the smoothing output, the ignition voltage of the series will be about 140 times the number used, and this should be rather more than the working voltage. (I find three in series light up at about 430 to 450 volts). The current taken by these lamps increases very rapidly indeed after the ignition voltage is passed, and this current discharges the condensers more rapidly than they can be recharged through the choke, so that the condenser P.D. soon drops below the extinction voltage and the lamps go out, thus smoothing off the voltage surge. I may say that although the ignition voltage of my arrangement is only some twenty volts above the working voltage, I have only once seen them light up and then only for an instant when the supply co-bungled a switching operation (for demonstration purposes I dim the output valve filaments with series resistance). This would seem to show that with normal operation voltage surges are negligible with A.C. rectified for H.T. supply, and the output valves lighted off the same transformer. There seems no reason why the neon lamp arrangements should not be adopted for D.C. smoothing circuits.

It may be noted that reversing the lamps in the holders varies the ignition voltage, and I understand that some of the "letter" lamps have quite large variations from the 140 volts suggested, so that it would probably be possible by judicious selection and choice of polarity to make a neon lamp surge absorber to operate at any desired voltage, within as close limits as would be required in practice.

(*f*) I cannot agree with Mr. Warren's statement that the use of a large condenser to reduce the voltage drop with A.C. is "unnecessary, since any voltage can be obtained with a transformer." The whole object of a large smoothing condenser is to minimise the voltage variation *during a cycle*, and putting up the transformer voltage will not help here. The argument put forward, namely, that we may increase the transformer voltage, would apply to a suggestion that resistance in smoothing chokes is not detrimental; but even this is only true within limits, as even with the Ferranti anode feed resistance scheme, it is possible to get motor boating with a multi-stage amplifier if the filter chokes have very high D.C. resistance (high compared to the anode feed resistances). I have even found it worth while to use specially low resistance chokes and to design the transformer to have as good voltage regulation from no load to full load as is practically possible with so small a piece of apparatus as a 100-watt transformer.

(*g*) I can recommend a two-stage filter rather than a single stage as cheaper for a given smoothing effect than a single stage.

(*h*) As additional proof that surges are not in fact as large as might be feared, I had an old smoothing circuit for 150 volts D.C. using the ordinary T.C.C. "300-volt-test" condensers, which are not recommended by the makers for eliminator use at all. When putting up the output power to 400 volts 60 milliamps., I could not obtain high voltage condensers at the moment, and I thought of trying the old ones "until they burnt out." They have not done so yet, although they ran for three months before being replaced by "600-volt-test," and several are still in use with anode feed resistances in earlier stages than the last.

I do not know what the final breakdown voltage of a common, green tin-cased condenser may be, but evidently for three months no surge voltage ever reached it, which tends to show that surge is not very troublesome in practice, (and also that the old tin-cased condenser with a compo top had an enormous factor of safety).

(*i*) Of course, rectifier transformers should be fused on both poles, 47 S.W.G. Eureka in removable clips is satisfactory.

C. R. COSENS.

To the Editor, E.W. & W.E.

SIR,—I thank Mr. Cosens for his letter. My comments on his criticisms follow.

(*a*) The resistance of the smoothing chokes was neglected for the sake of simplicity; it is easy to take it into account. With standard chokes, which may have a resistance of about five ohms per henry, the reduction in the surge voltage due to resistance is only about 5 per cent. With low-resistance chokes, designed to ease the smoothing, the reduction in the surge potential is less.

(*b*) I suggested on p. 606 that when working on rectified A.C. the surge at make is often limited by the rectifying system. This applies particularly when hot cathode valves are used as rectifiers.

(*c*) A voltmeter is of no value as a surge indicator. It only indicates the average voltage, which falls steadily to zero (see Fig. 7, p. 605). An oscillograph is required to indicate the instantaneous values, which may be quite high.

(*d*) A high resistance connected across the output condenser is useful if the set is switched off at the same time as the eliminator, though the set itself acts effectively as a discharger if the eliminator is switched off first. A high resistance has little effect upon the surge voltage.

(*e*) Surge absorbers are an added complication. It is clear that if they are necessary, one must be connected across each condenser; it is not sufficient to protect only the output condenser C_1 (ee Figs. 7, p. 605). My experience of neon lamps is limited, but it has been sufficient to convince me of their unreliability.

(*f* and *g*) Several points are involved here. Working on D.C. the only resistance to be considered is that of the choke, which behaves very much as the internal resistance of a high tension battery. If great, it may tend to motor boating. When working on A.C. there is nothing which directly corresponds; to talk of resistance of the smoothing circuit is almost meaningless. Back-coupling is induced chiefly through the impedance of the output condenser; in some cases it may actually be assisted by the by-pass condensers introducing a semi-resonant reaction into the L.F. amplifier. Choke resistance militates against smoothing and it is desirable to keep it low for this reason. From the point of view of *regulation* there is no particular virtue in a very low resistance. Even if the ohmic resistance were zero, the effective resistance of the smoothing circuit—condenser, choke, condenser—amounts to several hundred ohms. I agree that large condensers must give a smoother output, but I find it quite unnecessary to use higher values than those I have already suggested. I believe it is desirable to use a separate eliminator for the early valves, which require only a few milliamperes. Motor boating is thereby practically eliminated and a very smooth voltage is obtained for the detector valve. Using a single stage filter, having an L.C. product of 200 micro-farad-henrys, on the output valve I find, even with half-wave rectification, no appreciable hum with a M.C. speaker. If a hum occurs its cause must be sought elsewhere than in the smoothing circuit (see last paragraph of article, p. 606). Good smoothing is required for the detector valve; it is surprising how little smoothing is necessary elsewhere. I think two eliminators a cheaper and more satisfactory solution than one.

(*h*) I agree that condensers may often have an enormous factor of safety. From experience I know that waxed paper prepared and used under the best conditions rivals the best mica. The difficulty is to ensure such conditions in a factory routine. It is unsafe to depend upon much more than the maker's recommended voltages, though many condensers will stand much higher potentials. Mr. Cosens has been lucky, and so have I (as well as careful). But I have known of several less fortunate individuals.

(*i*) Fuses are of course desirable, but they will not save a condenser. A safety gap is better.

In conclusion, it may be emphasised that in the article not only was the nature of eliminator surges discussed, but it was also pointed out that proper design could eliminate over-voltage. It is true that various safety devices (when fitted) may mitigate the effects of over-voltage. With the Irish I agree, however, that prevention is the surest remedy.

A. G. WARREN.

The Transmitting Station Actually Sends Out Waves of One Definite Frequency, but of Varying Amplitude.

To the Editor, E.W. & W.E.

SIR,—In connection with the correspondence under the above heading in the November issue of *E.W. & W.E.* and Prof. Howe's reply, the following may be of interest as confirming the latter's views.

Suppose we have a telephony transmitter in which a modulated oscillator (or amplifier) is followed by a stage of high-frequency amplification which feeds the aerial. Let the carrier frequency be 1,000 kc. and suppose this to be modulated with a 1 kc. note. The output from the modulated oscillator will comprise frequencies of 999, 1,000 and 1,001 kc. The succeeding amplifier will not be working wholly on the linear portion of its characteristic and in its output there will be the usual series of harmonics. Of these, consider only the second. We are led to the conclusion that its output will include frequencies of 1,998, 2,000 and 2,002 kc. This is, of course, equivalent to a carrier frequency of 2,000 kc. modulated at 2 kc. Thus when listening to the second harmonic of such a transmitter all the notes should be raised an octave.

Experiment shows that no such effect is observed, a 1 kc. note is heard on the fundamental and on all harmonics.

My explanation is, that while it is legitimate, and even correct to view a modulated wave as a spectrum from the point of view of the tuning circuits, this course is not justified when dealing with a valve. The valve output is a definite function of the input to it, and hence, when dealing with it, it is necessary to consider the input as a complex waveform and not as a sum of pure frequencies of constant amplitude. The valve itself is quite aperiodic (over the frequency range involved) and is incapable of any harmonic analysis.

The conclusion is that both methods of viewing the modulated wave are of service but that one must not use them indiscriminately.

I shall be interested to hear if any of your readers can suggest any alternative and more acceptable explanation. The apparent fallacy was published in a letter to *The Wireless World* about two years ago, but no suggestions were offered by any of its readers.

FRANK AUGHTIE.

Teddington.
7th November, 1928.

BOOK REVIEW.

HANDBUCH DER EXPERIMENTAL PHYSIK (WIEN-HARMS), XIII. 2 Teil. Glühelektroden und Technische Elektronenröhren [Technical electronic valves and heated filaments.], pp. 492. Akademische Verlagsgesellschaft, Leipzig, 1928.

The first half of this book deals with thermionics, the scientific phenomena which underlie the behaviour of heated filaments; a general discussion of the thermodynamics of uncharged systems, electrically charged systems, and systems in electro-chemical equilibrium, clears the way for a comprehension of the facts of the emission of electrons by hot bodies. It is shown that an atmosphere of electron vapour may be considered as a perfect gas provided that the mean free path is sufficiently long; this condition demands that, as is practically always the case, the current density should not exceed a few amperes per cm.^{2}.

The equation for the emission of electrons in terms of the temperature of the source, first worked out by O. W. Richardson, is examined in detail, and the subsequent work of Langmuir and others on the emission from tungsten in the presence of vapours of alkali metals; thoriated tungsten and oxide covered filaments are included and a large number of curves and tables are reproduced; facts and theories of the shot and flicker effects terminate the first part of the book.

Sixty pages are then devoted to the production of wires of tungsten, molybdenum, and tantalum; several microphotographs show the crystalline state of these metals during drawing and recrystallising operations. The technique of oxide coating is gone into thoroughly and curves are given showing the decrease of emission with time for surfaces prepared by different methods. Methods of evacuating and outgassing valves are set out and a section is given to the various "getters" which are in use.

The remainder of the book, containing 130 pages, treats of the theory and practice of modern transmitters and receivers. The discussion is naturally severely condensed, but the recent advances, such as piezo-electric control, screened grids, and valve rectifying systems, are adequately dealt with. It is regrettable that the term "Durchgriff" should still be retained when its reciprocal, the voltage amplification factor, is now used by the whole world outside Germany.

The book should appeal to any serious student of wireless problems, to the mathematical physicist in search of interesting problems, and to the valve designer.

R. T. BEATTY.

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

Long-wave Radio Receiving Measurements at the Bureau of Standards in 1927.—L. W. Austin. (*Proc. Inst. Rad. Eng.*, September, 1928, V. 16, pp. 1252–1257.)

Illustrated by tables showing monthly averages of daylight signal intensities of a number of stations, European and American, and the strength of atmospherics. Although from January to May the intensities of the distant stations fell for the most part below the 1926 values, the averages (except for Bordeaux) were above those for 1926. Atmospheric disturbances have been very weak.

The Measurements of the Field Intensities of some High Power Long Distance Radio Stations. Part I. Bolinas and Bordeaux.—E. Yokoyama and T. Nakai. (*Researches of Electrot. Lab.*, Tokio, No. 229, June, 1928, 70 pages).

Field intensities were measured by the substitution method used by Beverage and Peterson, slightly modified. Intensities of "grinders" were measured by the method employed by Austin and Judson, also slightly modified.

The Daily Terrestrial Magnetic Variations: and the Sun's Magnetic Field.—S. Chapman. (*Nature*, 13th October, 1928, V. 122, p. 572.)

Referring to Gunn's suggestion (see October Abstracts) that the daily variation of the earth's magnetic field is due to the diamagnetism of the outermost layer of the atmosphere, the writer says that the magnetic effect is far outweighed by that of a drift acquired by the charges under the joint action of the magnetic field, gravity, and the vertical electrostatic field which prevents the light electrons from spreading upwards much farther than the heavier ions. He goes on to discuss briefly the effects of this drift, and mentions the possibility of its playing a part in the magnetic field of sunspots.

The Influence of the Earth's Magnetic Field on Wireless Transmission.—E. V. Appleton. (*International Union of Scientific Radio Telegraphy—U.R.S.I.*—July, 1928, V. 1, Fascicule 1, pp. 2–3, English, or Fasc. 1 *bis*, pp. 2–3, French.)

A summary of the paper read at the Washington Assembly, 1927. The magneto-ionic theory, previously developed, of the propagation of wireless waves in an ionised medium is here extended to the general case of propagation in any direction with regard to the magnetic field. The formula shows that only when the ionisation is small should critical effects occur for one of the two waves generally propagated, at about 200 metres: also, that under certain conditions, even vertical incidence on the layer may give reflection.

A Note on the Short Wave Long Distance Transmission.—T. Minohara and K. Tani. Also Diurnal Variation in Signal Strengths of Short Waves, and Seasonal Variation in Signal Strengths of the 20-metre Wave from Nauen in Japan.—T. Nakagami and T. Ono. (*U.R.S.I.*, July, 1928, V. 1, Fascicule 1—English, or Fasc. 1 *bis*.—French; pp. 44–51 or 37–44.)

The first paper gives some daily runs taken near Tokio on Buenos Ayres, Schenectady and Nauen, plotted in correlation with the width of the intervening "dark path." The titles of the other papers explain themselves.

Effective Heights of the Kennelly-Heaviside Layer in December, 1927, and January, 1928.—Breit, Tuve, and Dahl. (*Proc. Inst. Rad. Eng.*, September, 1928, V. 16, pp. 1236–1239.)

Results obtained by the echo-method with the improved transmission giving short widely-spaced peaks (see September Abstracts). Wavelength was about 75 m. Sometimes triple reflections were observed, corresponding to heights in the ratio 1, 2 and 4 (in a particular case, during a period of severe short-distance fading, 67, 140 and 280 miles). Heights (1st reflection) vary from 132 to 145 miles, though a 65–75 mile value recurs at the times of triple reflection, particularly in January. A table gives the daily measured effective heights and also rough estimates of the intensities of the waves recorded.

The Effect of Ozone on the Temperature of the Upper Atmosphere.—E. H. Gowan. (*Proc. Roy. Soc.*, 1st October, 1928, V. 120A, pp. 655–669.)

From material provided by other workers (*e.g.*, Abbot's curve of distribution of energy in solar spectrum: data as to total average amount of ozone, etc.), the writer considers the radiative equilibrium of the upper part of the atmosphere, taking into account the effects, with selective absorption, of water-vapour and ozone. The resulting curves indicate, among other things, a region of high temperature in the neighbourhood of, and above, 60 km. This agrees with deductions made from meteor observations and from acoustic observations on big explosions.

On the Diffraction of the Magnetic Electron.—C. G. Darwin. (*See* under "General Physical Articles.")

Long Wave Radio Reception and Atmospheric Ozone.—K. Sreenivasan. (*Nature*, 27th October, 1928, V. 122, pp. 646–647.)

The weekly averages of signal field strength at Madras from Bangalore, on a 4,000 m. wave, for

26 weeks from 1st March, 1927, are plotted in comparison with the corresponding weekly averages of ozone content measured in N.W. Europe. In spite of the 8,000 km. difference of locality, the curves show such a marked agreement that the writer deduces (a) that changes in the ozone values partake of the nature of a world phenomenon, and (b) that long wave field intensity is proportional to the ozone value of the air even when the averages are taken over such short periods as a week. It would appear likely that the reverse would be true with very high frequency waves, say below 100 m. wavelength. The diagrams also show the corresponding curves of sunspot numbers and of the mean magnetic character of day. Correlation of signals with the former are considered by the writer to be fairly definite: with the latter, no tangible connection is suggested.

GERMANS OVERCOME RADIO FADING.—(*Science News Letter*, 29th September, 1928, V. 14, p. 197.)

According to this report, Dr. Rukop announced at the recent meeting of the German Association corresponding to the "British Association" that fading on short waves can now be overcome by the use of two aerials at the receiving station, spaced perhaps 50 to 100 yards apart. No details, nor mention of any limitations, are given here.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

ZUR FRAGE NACH DER NATUR DER KUGELBLITZE (The Nature of Globular Lightning).—K. F. Bottlinger. (*Naturwiss.*, No. 13, 1928, p. 220.)

The nucleus is suggested to be temporarily radio-active matter produced by the breaking up of atoms by the enormous potential differences.

OBSERVATION, ENREGISTREMENT ET PRÉVISION DES ORAGES AU MOYEN DES ONDES ÉLECTRIQUES (Observation, recording and forecasting of Storms by Electric Waves).—A. Turpain. (*Rev. Gen. de l'Élec.*, 20th October, 1928, V. 24, pp. 584–587.)

The apparatus described and illustrated is based on a coherer of seven gilt needles. One modification records the energy of the discharge registered, by a bolometric circuit. The Turkish Government has installed over 30 of these instruments, including four of the bolometric type.

THE DIRECTIONAL OBSERVATIONS ON ATMOSPHERICS IN JAPAN.—E. Yokoyama and T. Nakai. (*U.R.S.I.*, July, 1928, V. 1, Fascicule 1—English, or 1bis — French, pp. 74–78 or 69–74.)

Results of observations at Isohama from February-July, 1927, on atmospherics interfering with long wave reception, chiefly 10,000 and 20,000 m. Among the conclusions drawn are: that not only is the direction of origin of "clicks" different from that of "grinders," but that the former come from less distant places than the latter; that the direction of "clicks" shifted from nearly south towards west as the season advanced from winter to summer, while that of the "grinders" remained unchanged; and, finally, that the "clicks" originate in the mountain regions of Japan, while the "grinders" probably come always from a tropical region such as the East Indies.

ELEKTRISCHE LEITFÄHIGKEIT DER ATMOSPHÄRE UND KONDENSATIONS-KERNZAHL (Electrical Conductivity of the Atmosphere and Condensation Nucleus Numbers).—J. Scholz. (*Naturwiss.*, 5th October, 1928, pp. 760–761.)

Further evidence of the correlation of these two properties, observed at the Meteorological-Magnetic Observatory at Potsdam.

RELATIONS ENTRE LES PARASITES ATMOSPHÉRIQUES ET LES PHÉNOMÈNES MÉTÉOROLOGIQUES (Relation between atmospherics and meteorological phenomena).—R. Bureau. (*U.R.S.I.*, July, 1928, V. 1, Fascicule 1, pp. 6–16.)

An exposition of the author's theory according to which he divides atmospherics into three classes: nocturnal (which he links up with meteorological anti-cyclonic conditions); irregular, appearing at any hour of day or night (linked to air-currents due to perturbations of the polar front); and afternoon, starting sharply about mid-day and decreasing at about 9 p.m. (linked to storm disturbances independent of the polar front). By "polar front" is meant the surface of encounter of masses of air from the polar regions with masses of air from tropical regions: this surface of encounter forms itself all round the earth at moderate latitudes. There are also the "pseudo-polar fronts," the most important one (for W. Europe) being born on the S.E. face of the Azores anticyclone by the meeting of Sahara and Atlantic airs. By means of records taken, some at sea in the N. Atlantic but most at Paris, the author correlates the observed atmospherics with the meteorological records of such "cold fronts"; and concludes that while in Europe the distance of the origin may lie between 50 and 150 km., in French W. Africa it may be as great as 300 km. Greater distances are only admitted as exceptional events caused by "particularly intense" cold fronts accompanied in general by violent storms.

THE POLARITY OF THUNDERCLOUDS AND THE INTERCHANGE OF ELECTRICITY BETWEEN THUNDERCLOUDS AND THE EARTH.—B. F. J. Schonland. (*Proc. Roy. Soc.*, 1st March, 1928, V. 118A, pp. 233–262.)

THE PRESENT STATE OF OUR KNOWLEDGE ON ATMOSPHERICS.—R. A. Watson Watt. (*Engineering*, 19th October, 1928, V. 126, p. 496.)

Summary of a paper read at the recent British Association meeting. Among other interesting points may be mentioned the fact that most of the many thousands of atmospherics whose shapes and magnitudes were discussed (observed in England, Khartoum and Australia) were of aperiodic form, and no reversal of voltage reaching 4 millivolts per metre could be measured. The mechanism by which these aperiodic forms are produced, whether by wide separation in time of the periods of acceleration and deceleration in the original discharge or by selective dissipation, is not yet understood: incidents in the propagation, rather than peculiarities at the source, may be responsible. At Aboukir the predominant stream of atmospherics arrives about noon from nearly due south, then swings round through west in the afternoon, and by 5 p.m. begins to come from the north-east. The sources of atmospherics seem to lie chiefly in the mountain areas; none are produced over the Pacific. Russian work has resulted in the location of thunderstorms 3,000 to 5,000 km. distant, the 10 kilocycle intensity component of the atmospherics observed being found to vary with the distance according to the inverse square law.

THE MECHANISM OF THUNDERSTORMS.—(*Engineering*, 19th October, 1928, V. 126, pp. 495–496)

Summary of the British Association discussion opened by G. C. Simpson and continued by C. T. R. Wilson, E. V. Appleton, B. F. J. Schonland, R. A. Watson Watt and J. J. Nolan.

MAGNETIC STORMS.—A. H. R. Goldie. (*Engineering*, 19th October, 1928, V. 126, p. 496.)

Summary of a paper read at the recent British Association meeting, dealing with conclusions drawn from observations at Lerwick, Eskdalemuir and Abinger.

SUN-SPOT NUMBERS AND ANNUAL RAINFALL IN NEW ZEALAND.—E. Kidson. (*N.Z. Journ. Sci. and Tech.*, July, 1928, V. 10, pp. 90–97).

THE VALUE OF MAGNETIC INVESTIGATIONS IN NEW ZEALAND AND SAMOA.—C. Chree. (*N.Z. Journ. Sci. and Tech.*, July, 1928, V. 10, pp. 97–100.)

PRESENT STATE OF KNOWLEDGE OF ATMOSPHERICS.—R. A. Watson Watt. (*E.W. & W.E.*, November, 1928, V. 5. pp. 629–632.)

PROPERTIES OF CIRCUITS.

DIE SELBSTERREGUNGSBEDINGUNGEN BEI RÜCKKOPPLUNGS-RÖHRENSENDERN FÜR SEHR KURZE WELLEN (Conditions for self-excitation in reactively-coupled valve transmitters for very short waves).—W. Pfitzer. (*E.N.T.*, September, 1928, V. 5, pp. 348–369.)

A long paper on work under the auspices of Prof. Barkhausen. Waves under 10 metres are considered, down to about 1.75 m. The theoretical conclusions of the first part are confirmed by experimental work with various types of circuit, all derived from the voltage-dividing connection, though externally not recognisable as such. Current measurements were made by a small incandescent lamp with thermopile, in a movable circuit which could be coupled to any desired part of the oscillating circuit. Excitation laws for waves 100 times longer, in similar circuits, were found to apply to these very short waves, except that below 2.5 m. small discrepancies appeared, due to the influence of the electron time of transit.

QUANTITAVES ZUR AUDIONGLEICHRICHTUNG (Quantitative Measurements on Audion-rectification).—M. v. Ardenne. (*Rad. f. Alle.*, October, 1928, pp. 433–436.)

Illustrated by curves taken with Telefunken-type valves on 400 m. wavelength.

ÜBER DIE EINEM EMPFÄNGER DURCH ERDUNG ZUGEFÜHRTE ENERGIE (The Energy introduced into a Receiver by Earthing).—A. Székely. (*Zeitschr. f. Hochf. Tech.*, September, 1928, V. 32, pp. 83–86.)

The writer concludes that the supplementary current produced by earthing is due less to the earth than to the effect of the vertical part of the earth-lead; and that the effect is only marked on short waves.

NOTE ON RADIO FREQUENCY TRANSFORMER THEORY.—Diamond & Stowell. (*Proc. Inst. Rad. Eng.*, September, 1928, V. 16, pp. 1194–1202.)

The writers state that computations based on hitherto accepted equations often fail to be in entire agreement with test results, and attribute this chiefly to the existence of a capacitive coupling whose effect is considered negligible in the usual analysis. They develop new equations which include this effect and which yield a closer agreement with experimental data. The variation with frequency of the equivalent transformer primary impedance is also affected by this distributed capacitive coupling.

ÜBER DEN RÜCKGEKOPPELTEN VERSTÄRKER (Amplifiers with Reaction coupling).—Y. Watanabe. (*Zeitschr. f. Hochf. Tech.*, September, 1928, V. 32, pp. 77–83.)

For various types of reactively-coupled amplifier, the equations are given for amplification factor, limits of amplification without oscillation, and coupling coefficient. A new reaction-circuit is mentioned which increases many times the amplification factor of the distortionless L.F. reactance amplifier. A method of solution is given for an amplifier with coupled resonance-circuit.

ON THE PREDETERMINATION OF OSCILLATING AMPLITUDES AND CIRCUIT CONSTANTS L, C AND M UNDER THE CONDITIONS OF MAXIMUM OUTPUT OF TRIODE OSCILLATORS.—K. Kurokawa and H. Hayakawa. (*Journ. I.E.E. of Japan*, August, 1928, pp. 796–815.)

The static characteristic surfaces of the plate current as a function of plate and grid voltages are assumed to be represented by parts of four planes mutually intersecting. The current and voltage amplitudes of the oscillating circuit are calculated from the conditions of equality of mean power supplied to the oscillating circuit by the source and the valve, and that consumed in the oscillating circuit (neglecting the grid circuit loss). Values for L, C and M giving the maximum output for a specified frequency are calculated.

EIN EXPERIMENTELLER BEITRAG ZUM SPULENPROBLEM (An experimental contribution to the coil problem).—R. Rücklin. (*Arch. f. Elektrot.*, 17th September, 1928, V. 20, pp. 507–532.)

The problem of current and voltage distribution for high frequency in a single-layer cylindrical coil leads to different solutions by different workers, some saying that the distribution is sinusoidal for all frequencies, others that there is a critical frequency at which it changes to hyperbolic. These tests tend to show that there is such a change at a critical frequency.

ZWEI VERSTÄRKER MIT OHMSCHER RÜCKKOPPLUNG IN THEORETISCHE BEHANDLUNG (Two Amplifiers with Resistance Reaction, treated theoretically).—F. Schierl. (*Arch. f. Elektrot.*, 11th August, 1928, V. 20, pp. 346–370.)

Theoretical results are confirmed experimentally. The two amplifiers are the 2-valve circuit known as the kallirotron of Turner, and a somewhat similar circuit but using 2-grid valves, due to Jäger and Scheffers. With each of these, increase of back-coupling resistance causes increase in the characteristic steepness, which may become infinite—when instability and "flaws" appear in the plotting. Finally, the practical application of these two amplifiers to the measurement of small A.C. currents is dealt with. The effect of inductance in the anode circuit on the amplification is discussed.

UNTERSUCHUNGEN AN DER DOPPELGITTERRÖHRE IN RAUMLADUNGSNETZSCHALTUNG (Investigation of double-grid valves in space-charge-net connection).—J. Dantscher. (*Arch. f. Elektrot.*, 11th August, 1928, V. 20, pp. 333–345.)

The functioning of the 2-grid valve in this connection, in the region of saturation, is studied by means of static characteristic curves. A series of current-voltage curves are given. A number of conclusions are drawn, for which the paper must be consulted. Mention can be made here of two: as a result of the non-rectilinear slope of the grid characteristic, for full control the amplification is not completely free from distortion; and the value of "durchgriff" is even more dependent on conditions of employment than in the case of a single-grid valve.

EINIGE ERGÄNZUNGEN UND BERICHTIGUNGEN ZUM PROBLEM DER KIPPSCHWINGUNGEN (Some Amplifications and Corrections on the Problem of Relaxation Oscillations).—E. Friedlander. (*Arch. f. Elektrot.*, 7th June, 1928, V. 20, pp. 158–161.)

Refers to previous papers by the same writer (see Abstracts 1927, p. 51) and to van der Pol's work (see there and also various recent Abstracts). Goes on to give a provisional table showing the production of harmonic, relaxation, and combined har. and relax. oscillations according to the number of frequency-determining, energy-storing elements present in the circuit; with examples of each class. Thus in the class of 2 elements, for Relax. osc. alone is given the Abraham-Bloch Multivibrator circuit; in the 3 element class, for mixed har. and relax. osc., the Flewelling circuit is given. Finally, various cases of relaxation oscillations in everyday life are mentioned, including water-hammer effects in water systems, and effects in A.C. arcs.

AN EXPERIMENTAL INVESTIGATION OF FORCED VIBRATIONS.—L. W. Blau. (*Journ. Franklin Inst.*, October, 1928, V. 206, p. 502.)

Corrections to the paper under this title (November Abstracts).

LE BATTEMENT DU CŒUR CONSIDÉRÉ COMME OSCILLATION DE RELAXATION, ET UN MODÈLE ÉLECTRIQUE DU CŒUR (Heart-beat as an Oscillation of Relaxation, and an Electric Model of the Heart).—B. van der Pol and J. van der Mark. (*L'Onde Élec.*, September, 1928, pp. 365–392.)

The first part of this paper shows how the equation which for certain conditions of resistance, inductance and capacity leads to the ordinary sinusoidal damped waves leads also, for other conditions, to the production of the totally dissimilar oscillations of relaxation; discusses the properties of these, in particular their property of putting themselves in synchronism with an external periodic phenomenon acting on them; and some of the processes in which they occur (*e.g.*, in the production of sound by a flute). It then goes on to establish the analogy between the processes of these oscillations and the beating of the heart; not insisting that any electric excitation causes or precedes the contractions of the heart, but considering the two processes as parallel examples of the same mathematical behaviour. Thus the knowledge recently obtained regarding the electrical oscillations allows the cardiac rhythm to be considered from a new point of view; for example, well-known irregularities of the heart can be predicted and in addition some which so far are unknown as regards the human heart. The whole of the rest of the paper is devoted to an actual electrical circuit representing the heart, and to electro-cardiograms taken from it.

TRANSMISSION.

VACUUM TUBES AS OSCILLATOR GENERATORS.—D. C. Prince and F. B. Vogdes. (*G.E. Review*, October, 1928, V. 31, pp. 546–554.)

Part VI of this series deals with secondary grid-coupled circuits: power-amplifier and master-controlled circuits.

CONSIDERATIONS AFFECTING THE LICENSING OF HIGH-FREQUENCY STATIONS.—S. C. Hooper. (*Proc. Inst. Rad. Eng.*, September, 1928, V. 16, pp. 1240–1251.)

The writer deals with frequencies between 6 and 23 megacycles, which he considers must generally be considered as interfering around the world. The article includes a suggested table of priority among applicants in the fixed service bands; and the writer points out that places must be found in the spectrum for other uses of radio:

for instance, channels between 80 and 500 kc. will be required for television. See also Espenschied, September Abstracts.

NOTE AU SUJET DES ONDES DE QUELQUES MÈTRES (Note on Waves of a few metres length).—R. Mesny. (*U.R.S.I.*, July, 1928, V.1, Fascicule 1—French, or 1 *bis*—English, pp. 42–44 or 35–37.)

Wavelength was from 2 to 4 m.; power from 2–200 W. Reception was by super-regenerative circuits. Propagation between raised positions within sight of each other was excellent; in the Alps between two peaks 100 km. apart, reliable duplex telephony needed only 3 W. input; as might indeed be expected, since the formula gives at this distance for this wavelength (assuming a transmitter isolated in space, and no damping) a field-strength of 67 microvolts per metre for every watt of energy radiated.

The effect of a screen was tested by interposing a chain of hills about 25 km. away. In all cases, the signals vanished somewhat abruptly when the line joining the receiver and the edge of the screen made an angle of 1° to 1.5° with the line passing directly to the transmitter. Propagation near the ground presented very different phenomena. With transmitter and receiver a few metres above flat open ground, the same 3 W. input gave communication vanishing between 2 and 3 km. Even if the transmitter remained high (*e.g.*, at the top of the Eiffel Tower) the signals disappeared at some 20 km. if the receiver was on a plateau a few hundred metres from the near edge; though if it was moved to that edge, the signals again became strong. This is interpreted as a case of reflection of plane waves at a plane, which by calculation would cause a field nearly 25 times weaker at the interior of the plateau than at the edge, where reflection does not come in. With the transmitter at the top of the Eiffel Tower, powers of 150 W. gave no result at distances of 600 and 900 km., where the sphericity of the earth constitutes a screen 7 km. high. Only ionic refraction could permit such communication, and apparently this is insufficient to bring back, even at greater distances, waves lower than about 10 metres. The uses of such short waves are discussed. Atmospherics were absolutely imperceptible (as was also found by Esau). Cf. the latter's paper, November Abstracts, for points of agreement and of contrast.

RECEPTION.

RADIO RECEIVER VOLUME CONTROL.—A. B. Whittaker. (*Elec. Review*, 26th October, 1928, V. 103, pp. 703–704.)

Comments on the various applications of variable resistance as a means of control.

L'EVOLUTION ET L'AVENIR DES HAUT-PARLEURS (The Evolution and Future of Loud Speakers).—P. Toulon. (*L'Onde Élec.*, September, 1928, pp. 393–409.)

The writer evidently places great faith in the future of the electrostatic loud-speaker, a present form of which he describes and illustrates. Field voltage used is about 2,400 V.

RESONANCE IN MOVING-COIL LOUD SPEAKERS. THE IMPORTANT INFLUENCE OF THE DIAPHRAGM SURROUND, AND ITS QUANTITATIVE ANALYSIS.—N. W. McLachlan. (*Wireless World*, 10th and 17th October, 1928, V. 23, pp. 497–499 and 539–542.)

THE KILO-MAG FOUR: A SCREENED GRID SET WITH A THOUSAND-FOLD H.F. AMPLIFICATION.—H. F. Smith. (*Wireless World*, 24th October, 1928, V. 23, pp. 550–554.)

FURTHER NOTES ON THE "MEGAVOX THREE."—N. W. McLachlan. (*Wireless World*, 3rd October, 1928, V. 23, pp. 458–460.)

The numerical treatment of signal voltages is first dealt with, on the foundation provided by the Barfield field strength contour map of 2LO, which is reproduced. The question of smooth volume control is then considered.

FADING AND THE DETECTOR: ADVANTAGES OF LEAKY GRID DETECTION IN MINIMISING EFFECTS OF FADING.—(*Wireless World*, 3rd October, 1928, V. 23, p. 485).

VALVES AND THERMIONICS.

ELEKTRONENSTRÖME UND RAUMLADUNG IN DICHTEN GASEN (Electron-currents and Space-charge in dense gases).—F. Skaupy and W. Daudt. (*Phys. Zeitschr.*, 1st May, 1927, pp. 313–315.)

Skaupy showed in 1918 that amplifier valves with Nitrogen, or Argon plus Nitrogen, at pressures of the order of ⅔ atmosphere, showed the same effects (if weaker) as vacuum valves. The present paper develops the experiments still further; characteristic curves are shown, one diagram, for instance, giving curves for various pressures of N_2; a second, for various anode voltages from 100 to 220 V. at a constant pressure of 300 mm. of N_2; and a third, for the effects of various impurities in the gas.

SCREENED-GRID VALVE AS A DETECTOR: SOME INTERESTING DATA BASED ON ACTUAL MEASUREMENT.—A. P. Castellain. (*Wireless World*, 10th October, 1928, V. 23, pp. 492–494.)

OSCILLATIONS IN IONISED GASES.—I. Langmuir. (*Proc. Nat. Acad. Sci.*, August, 1928, V. 14, pp. 627–637.)

A theoretical analysis, with experimental confirmation, of various possible modes of vibration of a "plasma"—a highly ionised gaseous medium at low pressure containing positive ions and electrons normally in about equal numbers, so that the resultant space charge is very small.

Oscillations of small amplitude with frequencies up to 1.2×10^9 have been observed, explained by the theory as being low-velocity electron waves with zero group velocity and therefore incapable of transmitting energy. Other vibrations, electrical analogues of sound waves, with frequencies ranging from 1 to 240 kilocycles, are due to ionic oscillation. Oscillations in a beam of electrons, having different frequencies according to the direction from which they are observed, have frequencies ranging from 10^7 to 10^8.

Recherches et Essais sur les Lampes de T.S.F. (Research and tests on Wireless Valves).—A. Kiriloff. (*Q.S.T. Fran.*, October, 1928, pp. 7–18.)

The first of a series of articles. The present part deals with the installation of the laboratory, transformer and rectifier room, and machine room.

Graphs for the Design of Bright-emitting Tungsten Filaments.—N. Kato. (*Electrot. Lab. Tokyo*, Circ. No. 50, February, 1928, pp. 1–14.)

Empirical Formulæ for Dependence of Tungsten Resistance on Temperature.—N. D. Morgulis. (*Teleg. i Telef. b.p., Nichny-Novgorod*, August, 1928, V. 9, pp. 485–486.)

DIRECTIONAL WIRELESS.

Radio Beacons for Transpacific Flights.—C. C. Shangraw. (*Proc. Inst. Rad. Eng.*, September, 1928, V. 16, pp. 1203–1235.)

Deals with the "equi-signal zone" system (*cf.* various recent Abstracts) in particular connection with various recent long-distance flights. The width of the zone appears to be about 8 miles at a distance of about 1,200 miles. Reception on the aeroplane would seem to be the weakest part of the system. Even with the best transmitting and receiving apparatus, adequate training of personnel is necessary.

Experiences in Radio Compass Calibration.—F. A. Kolster. (*U.R.S.I.*, July, 1928, V. 1 Fasc. 1—English, or 1 *bis*—French, pp. 40 or 33.)

Abstract of paper read at the Washington Assembly, 1927.

MEASUREMENTS AND STANDARDS.

A Frequency Standard.—W. A. Marrison. (*Nature*, 6th October, 1928, V. 122, p. 552.)

Summary of an article in the Bell Lab. Record for August. Engineering physicists are beginning to question whether the accuracy of the rate of the earth's rotation round its axis is sufficient for their measurements. If the length of the day alters by about one second in ten years, this would soon cause an appreciable discrepancy between reference standards. Marrison points out that in electrical communication we have to work with frequencies ranging from less than unity to a hundred million or more per second. It seems now possible to maintain frequencies constant to one part in ten million, for several seconds. In fact, in successful television this is done. He goes on to describe the Bell Company's new form of quartz-controlled reference standard and the clock-equipment used to determine the frequency. The crystal temperature is controlled to within about one-hundredth of a degree centigrade. The clock, controlled by the crystal oscillator, keeps time with a maximum inaccuracy of less than one-tenth of a second per day.

Limits of Accuracy in Physical Measurements.—A. E. Ruark. (*Proc. Nat. Acad. Sci.*, April, 1928, V. 14, pp. 322–328.)

Methoden der Vakuumbestimmung an Fertigen Glühlampen (Methods of determining the vacuum of a completed incandescent lamp).—P. Selenyi. (*E.T.Z.*, 27th September, 1928, p. 1443.)

Zur Berechnung der Schallenergie (The calculation of Sound Energy).—V. Weisskopf. (*Phys. Zeitschr.*, No. 10, 1928, V. 29, pp. 302–304.)

The writer points out that it has hitherto been the custom to neglect variations of the second order of magnitude in pressure and volume-changes, but that this is inadmissible as the factors thus neglected can have a harmonic-producing effect.

The Use of a Wente Condenser Transmitter to Measure Sound Pressures in Absolute Terms.—A. J. Aldridge. (*P.O. Elec. Eng. Journ.*, October, 1928, V. 21, pp. 223–225.)

Unless suitable corrections are made, certain errors—here indicated—may be involved.

Appareil de Tableau Permettant de Mesurer par Lecture Directe les Différents Éléments d'un Circuit Complexe sous Courant Alternatif (Measuring instrument reading directly the various elements of a complex A.C. circuit).—S. S. Held. (*Rev. Gén. de l'Élec.*, 29th September, 1928, V. 24, pp. 465–471.)

Description of the "Henrymeter" and the ways of connection enabling it to read direct values of L, C and R, independent of voltage and frequency within industrial limits.

The Standardisation of Stationary Secondary Cells in the British Post Office.—H. C. Jones. (*P.O. Elec. Eng. Journ.*, October, 1928, V. 21, pp. 227–235.)

Subsidiary points of interest are the use of the "Electrode Cadmium" as a means of detecting trouble in individual cells: and the employment of anti-spray oil film.

Über neuere akustische und insbesondere elektroakustische Arbeiten (Latest work on acoustics, and in particular electro-acoustics).—F. Trendelenburg. (*Zeitschr. f. Hochf. Tech.*, September, 1928, V. 32, pp. 94–99.)

Second part of the long survey referred to in October Abstracts. This part deals with sound-field processes and the acoustics of rooms, both theoretically and experimentally. Sabine's researches on small scale models are mentioned, and illustrated by photographic representations of a vertical section of a theatre showing the course of a sound wave and the formation of reflection waves, particularly from the dome: showing also the improvements resulting from changes made in the model. Oscillograms also are given of echo-duration measurements on different frequencies of test-note. Reference is made to the treatment of broadcasting studios.

Hochvakuum-Messeinrichtung für Grossgleichrichters (High Vacuum Indicator for large Rectifiers.)—W. Menger. (*E.T.Z.*, 11th October, 1928, pp. 1512–1513.)

An appliance (by which an eye can be kept on the state of the vacuum) depending on the fact that the heating of a wire traversed by a constant current depends on the vacuum surrounding it.

Messung von Magnetischen Feldern und Feldänderungen mit dem Magnetron (Measurement of Magnetic Fields and Field-changes by the Magnetron.)—M. Rössiger. (*E.T.Z.*, 11th October, 1928, p. 1513: summarised from *Zeitschr. f. Phys.*)

The writer uses a Hull Magnetron for determining the total intensity and the variations of the earth's magnetic field. A sensitivity of 10^{-5} Gauss is obtainable.

Mesures et Essais Effectués avec L'Antenne Projecteur S.F.R.—C.M. (Measurements and Tests on the Soc. Fran. Radioélec. Chireix-Mesny Beam Aerial).—(*Bull. d.l. Soc. Fran. Rad. Él.*, June, 1928, pp. 22–27.)

Measurement of Radio Field Intensity.—V. I. Bashenoff. (*Teleg. i. Telef. b.p., Nichny-Novgorod*, August, 1928, V. 9, pp. 385–410.)

General Method for Plotting Modulation Characteristics of Radio Telephone Transmitters.—N. D. Smirnov. (*Teleg. i. Telef. b.p., Nichny-Novgorod*, August, 1928, V. 9, pp. 478–484.)

Mesures Électrométriques de Très Faibles Différences de Potentiel Alternatives (Electrometer Measurements of very small A.C. Potential Differences).—Gutton and Laville. (*Phys. Berichte*, 1st July, 1928, p. 1174. from Comptes Rendus, 1924.)

The moving system weighed only 15 mg., and 1 volt gave a spot deflection of 100 mm.

Dielektrische Messungen an Einem Cellon-kondensator bei mittleren Frequenzen und Niederspannung (Dielectric Measurements on a "Cellon" Condenser at Medium Frequencies and Low Voltages).—W. Hubmann. (*Arch. f. Elektrot.*, 11th August, 1928, V. 20, pp. 371–373.)

New Precision in Cosmic Ray Measurements, Yielding Extension of Spectrum and Indications of Bands.—R. A. Millikan and G. H. Cameron. (*Phys. Review*, June, 1928, V. 31, pp. 921–930.)

A method is described which leads to greatly increased precision in the measurement of capacities of the order of one E-S. unit—giving results accurate to about 1 in 1,000. With the new electroscopes and methods, more penetrating cosmic rays have been detected and measured than the hardest hitherto found.

A Method of Calibrating a Low Frequency Valve Generator with a Single Frequency Standard Source.—T. S. Rangachari. (*E.W. & W.E.*, November, 1928, V. 5, pp. 633–634.)

Scientific Instruments at Olympia.—(*E.W. & W.E.*, November, 1928, V. 5, pp. 620–628.)

SUBSIDIARY APPARATUS AND MATERIALS.

The Element of Time in the Photoelectric Effect.—E. O. Lawrence and J. W. Beams. (*Phys. Review*, September, 1928, V. 32, pp. 478–485.)

Experiments are described on the time-variation of the photoelectric emission from a metal surface illuminated by light flashes of 10^{-8} sec. duration. They have yielded information as to the speed of operation of the Kerr cell electro-optical shutter (August Abstracts) and have made possible for the first time the observation of the steepness of wave fronts (resulting from spark discharges) travelling along wires.

L'Emploi de Cellules Photoélectriques, associées à des Lampes à plusieurs Électrodes, à la Solution de divers Problèmes concernant la Mesure du Temps (The Use of Photoelectric Cells associated with multi-electrode Valves, for the solution of various Time-measuring Problems).—G. Ferrié and R. Jouaust. (*U.R.S.I.*, July, 1928, V. 1, Fascicule 1—French—or 1 *bis*—English; pp. 21–28 or 12–19.)

The self-maintained photoelectric pendulum finally evolved would keep time to within $\frac{1}{100}$ sec. or less after 24 hours if the supply voltage were kept constant during that time.

Photo-electric Thresholds and Fatigue.—G. B. Welch; and The Potential of Photo-active Cells containing Fluorescent Electrolytes.—H. W. Russell. (*Phys. Review*, October, 1928, V. 32, pp. 657–666, 667–675.)

Über einen Kathodenoszillographen hoher Spannungsempfindlichkeit (A Cathode-ray Oscillograph of High Voltage-sensitivity).—E. Sommerfeld. (*Arch. f. Elektrot.*, 17th September, 1928, V. 20, pp. 607–618.)

A hot cathode instrument using low voltages (round 1,000 V). For obtaining as small a surface of emission as possible, the point and hood arrangement described by Rogowski and Grosser is used, modified slightly. It was found that for the low voltages employed, the vacuum had to be very high—less than 10^{-6}mm. Internal photography is used; an accelerating grid close to the screen, and with a voltage between it and the screen, speeds up the electrons. Greatest sensitivity so far is 0.1 cm./volt.

EMPFINDLICHER GLÜHKATHODENOSCILLOGRAPH FÜR INNENAUFNAHMEN IN EINEN VORVAKUUM (A sensitive Hot Cathode Oscillograph for Internal Photography in an ante-vacuum).—W. Rogowski, E. Sommerfeld and W. Wolman. (*Arch. f. Elektrot.*, 17th September, 1928, V. 20, pp. 619–624.)

Discusses Sommerfeld's above-described apparatus, and points out the practical difficulties due to the high vacuum. Improvements are mentioned—*e.g.*, a method of avoiding having to renew the high vacuum each time the photographic plate is removed, by substituting a thin fluorescent plate (a fixed part of the main tube) and allowing the fluorescence of this to mark the photographic plate. To prevent this thin plate from being forced in by atmospheric pressure, an "ante-vacuum" is used in the container for the photographic plate; this vacuum has to be renewed each time, but need not be high—1 mm. is enough. Many photographic records thus taken are shown.

NEUERE UNTERSUCHUNGEN AN KOHLEMIKROPHONEN (New Investigation of Carbon Microphones).—C. A. Hartmann. (*E.N.T.*, September, 1928, V. 5, pp. 344–347.)

The writer refers to a previous paper in which he pointed out that not only the frequency-dependence, but also the non-linear property of a microphone affects transmission, the latter cause producing overtones and a displacement of the amplitude of the partial tones. "Amplitude curves" of a microphone illustrate this and give a measure of the effect. The present tests were chiefly on a high-grade microphone, and show that for medium sound-pressures the non-linearity is reasonable, but that for small pressures, near the threshold point, there is great room for improvement.

MORE POWERFUL CATHODE RAYS.—(*Journ. Am. I.E.E.*, October, 1928, V. 47, p. 756.)

A paragraph referring to improvements in the Coolidge tube due to Plauson in Germany: consisting in the use of beryllium instead of nickel for the window, and of a rotating magnetic field for controlling the electron stream. Great intensification of ionic activity is said to result. Somewhat sensational claims appear to be made.

AVERTISSEUR AUTO-ALARME SYSTÈME S.F.R.-CHAUVEAU (Automatic Distress Call System S.F.R.-Chauveau).—(*Bull. d.l. Soc. Fran. Rad. Él.*, July-August, 1928, pp. 3–17.)

Description, with test results over distances up to 200 miles, of the S.F.R. ship call apparatus working on the standard minute call of 12 four-second dashes spaced by 1 sec. intervals. To provide the latitude necessary in view of incomplete and hand-sent calls, the apparatus will respond to three consecutive dashes between 3 and 5 seconds each and spaced by intervals below 2 seconds.

GLEICHSTROM - HOCHSPANNUNGSMASCHINEN ALS ANODENGENERATOREN (D.C. High-tension machines for anode supply).—H. Schulthess. (*E.T.Z.*, 18th October, 1928, pp. 1542–1543.)

Results with dynamos giving 12,000 V lead to the hope that similar success will be obtained with machines for 20,000 V. 20 kW. appears to be the smallest economical size.

EIN GLEICHSTROM-WECHSELSTROM-UMFORMER FÜR JENE, DIE EIN GLEICHSTROM-LICHTNETZ IN IHRER WOHNUNG HABEN (a D.C.-A.C. Converter for use on D.C. Power Supply).—F. Gabriel. (*Rad. f. Alle*, October, 1928, pp. 437–448.)

Illustrated description of a complete "home" unit designed round a 160 W. D.C. motor driving to 70 W. A.C. generator. The article is followed by two pages on the subject "Are D.C. Mains-adapters dangerous?" by Dr. Göttinger.

ON THE ACTION OF THE GEIGER COUNTER.—L. F. Curtiss. (*Phys. Review*, June, 1928, V. 31, pp. 1060–1071.)

A PORTABLE OSCILLOGRAPH EQUIPMENT FOR THE OBSERVATION OF TRANSIENT ELECTRICAL PHENOMENA.—P. R. Coursey. (*E.W. & W.E.*, November, 1928, V. 5, pp. 616–619.)

SURGES IN ELIMINATOR SMOOTHING CIRCUITS.—A. G. Warren. (*E.W. & W.E.*, November, 1928, V. 5, 601–606.)

STATIONS, DESIGN AND OPERATION.

THE USE OF RADIO FIELD INTENSITIES AS A MEANS OF RATING THE OUTPUTS OF RADIO TRANSMITTERS.—S. W. Edwards and J. E. Brown. (*Proc. Inst. Rad. Eng.*, September, 1928, V. 16, pp. 1173–1193.)

A method is described, with examples based on field strength surveys and other tests on five broadcasting stations, by which the outputs of transmitters could be regulated by the authorities in terms of field intensities instead of watts power in the transmitter or aerial circuits. The writers consider that stations should be so licensed that the largest possible number of listeners should receive signals of 5 to 30,000 microvolts per metre, while signals above the 30,000 should be considered as of interfering strength.

TECHNISCHES NACHRICHTENWESEN IN DER REICHSWEHR (Communication-technique in the National Army).—Pleger. (*E.T.Z.*, 11th October, 1928, pp. 1519–1522.)

A semi-popular lecture before a branch of the Elektrotechnischer Verein.

RÉGULATEUR AUTOMATIQUE DE FRÉQUENCE POUR POSTES ÉMETTEURS À ONDES COURTES (Automatic Frequency Regulator for Short Wave Transmitting Stations).—(*Bull. d.l. Soc. Fran. Rad. Él.*, January, 1928, pp. 3–13.)

Description of the S.F.R. system of frequency stabilisation, depending on the formation of beats between the transmitter oscillations and those of a standard low-power oscillator; the rectification and amplification of these beats in such a way that the final output is proportional to the frequency of the beat-note; and the action of this output in the saturation-winding of a specially designed iron core choke whose H.F. winding is coupled to the main transmitter circuit. In this way small rapid variations of frequency are compensated for, while slow variations of greater magnitude are attended to by a variable air condenser electromagnetically controlled by the same regulating current.

GENERAL PHYSICAL ARTICLES.

INFLUENCE OF TEMPERATURE ON THE RAMAN EFFECT.—K. S. Krishnan. (*Nature*, 27th October, 1928, V. 122, p. 650.)

The new lines in the spectrum of the scattered light are due to the result of inelastic collisions of the light quanta with the molecules of the medium (giving a frequency-shift towards a longer wavelength) or of super-elastic collisions (giving a shift towards a shorter wavelength). As the temperature rises, the number of molecules in a position to communicate energy to the light quantum should increase, so that the proportion of super-elastic to inelastic collisions should increase. The writer brings experimental proof that such actually happens, the shorter wavelength lines increasing in intensity with rise of temperature, and the longer decreasing.

THE RAMAN EFFECT IN HIGHLY VISCOUS LIQUIDS, S. Venkateswaren; and WAVELENGTH SHIFTS IN SCATTERED LIGHT, W. H. Martin. (*Nature*, 6th October, 1928, V. 122, pp. 506–507.)

New results and deductions on the subject of Raman's new type of secondary radiation.

DÉPOLARISATION DES RADIATIONS SECONDAIRES DANS LA LUMIÈRE COMPLEXE QUI RÉSULTE DE LA DIFFUSION MOLÉCULAIRE D'UNE RADIATION MONOCHROMATIQUE (Depolarisation of Secondary Radiations in Complex Light, resulting from Molecular Diffusion of a Monochromatic Radiation).—J. Cabannes. (*Comptes Rendus*, 15th October, 1928, V. 187, pp. 654–656.)

The writer's measurements of the depolarisations of the Raman secondary radiations lead to the conclusion that the action of the light on the molecule depends on the orientation of the latter. The writer suggests that it would be interesting to study from this point of view crystals in which the molecules are oriented according to a few known directions.

THE ABNORMAL SPECIFIC HEAT OF A RAREFIED GAS AT A LOW TEMPERATURE: AND THE COSMIC RADIATION.—R. D. KLEEMAN. (*Summary in Physik. Berichte*, 1st October, 1928, p. 1825.)

The conditions in interstellar space and at the border of the earth's atmosphere are explained to be such that the highly energised gamma rays are endowed with the penetrating properties found in the "cosmic" radiation.

EXPERIMENTAL PROOF OF "NEGATIVE DISPERSION."—Kopfermann and Ladenburg. (*Nature*, 22nd September, 1928, V. 122, pp. 438–439.)

AVAILABLE ENERGY.—R. A. Millikan. (*Nature*, 6th October, 1928, V. 122, pp. 555–556.)

A summary of a Messel memorial address. The two chief problems dealt with are: (1) where in the universe do the atom-building processes proceed?; and (2) why have not the primordial positive and negative electrons, which go to build up the common elements, been used up long ago?

THE ORIGIN OF THE COSMIC RAYS.—R. A. Millikan and G. H. Cameron. (*Phys. Review*, October, 1928, V. 32, pp. 533–557.)

A short abstract is impossible. One point may be mentioned: the observed properties of the rays, indicating that the creation of the common elements occurs only in interstellar or intergalactic space, and *not* in the stars, suggests the possibility of avoiding the "Wärme-tod" (the ultimate disappearance of all available energy, necessary according to Jeans' theory that atoms and molecules are everywhere convertible into radiant energy but that the process is nowhere reversible; and apparently also according to the opposed theory of Stern, Tolman and others, that the foregoing processes are all everywhere reversible) and of regarding the universe as already in "the steady state."

THE MAGNETIC MOMENT OF THE ELECTRON.—G. Breit. (*Nature*, 27th October, 1928, V. 122, p. 649.)

ON THE MAGNETIC MOMENT OF THE ELECTRON.—C. G. Darwin. (*Proc. Roy. Soc.*, 1st October, 1928, V. 120A, pp. 621–631.)

There are certain problems in which it is convenient to attribute part of the magnetic field of a moving electron to an electric convection current and part to its intrinsic magnetisation; *e.g.*, in discussing the Stern-Gerlach effect for free electrons. The present paper effects this separation, the formulæ being worked out first for slow motions and then generalised for high speeds by relativity principles.

ON THE DIFFRACTION OF THE MAGNETIC ELECTRON.—C. G. Darwin. (*Proc. Roy. Soc.*, 1st October, 1928, V. 120A, pp. 631–642.)

Author's summary: The problem is solved of the diffraction of an electron wave by a line-grating exerting periodic electric or magnetic forces; this represents the essential features of diffraction by a crystal. The incident wave is supposed to be magnetised in a definite direction, and it is shown that when the grating exerts only electric forces, the effect is to rotate the direction of magnetisation through a definite angle about an axis perpendicular to the incident and diffracted rays, and no polarisation can be produced by the diffraction. For some magnetic forces a similar rotation occurs, but in general the simultaneous action of electric and magnetic forces may produce a partial polarisation, though the case is too remote from experiment to be worth treating in detail.

Über die Winkelverteilung Langsamer Elektronen beim Durchgang durch Metallhaüte (The Angular Dispersion of Slow Electrons on Passage through Metal Films).—E. Rupp. (*Ann. d. Physik*, No. 8, 1928, V. 85, pp. 981–1012.)

De Disperso-electriciteit ("Disperso-electricity").—H. G. Bos. (*Summary in Physik. Berichte*, 1st October, 1928, pp. 1767–1768.)

Deals with the electricity produced by the dispersion of a liquid in a gas. Previous results have been inconsistent and irregular, and the writer has set up a "dispersometer" to clear up the phenomenon.

The Revolution in Physics.—Oliver Lodge. (*Journ. I.E.E.*, October, 1928, V. 66, pp. 1005–1020.)

The nineteenth Kelvin Lecture, with four Supplements.

Untersuchungen über den Elektrischen Durchschlag und Überschlag in unhomogenen Felde (Investigations of Electrical Breakdown and Flashover in a Field which is not Homogeneous).—E. Marx. (*Arch. f. Elektrot.*, 17th September, 1928, V. 20, pp. 589–606.)

In connection with point and plate discharges, through solids, liquids and gases, particular stress is here laid on the influence of polarity and of the duration of the voltage impulse. Some specially beautiful photographs are shown.

Interferenzerscheinungen bei Korpuskularstrahlen (Interference Phenomena in Corpuscular Radiation).—W. Elsasser. (*Naturwiss.*, 14th September, 1928, pp. 720–725.)

A review of the methods and results of the various workers in this field, including Davisson and Germer, G. P. Thomson, E. Rupp and E. G. Dymond.

Stossspannungen und Funkenbilder (Shock-voltages and Spark-pictures).—W. Rogowski and R. Tamm. (*Arch. f. Elektrot.*, 17th September, 1928, V. 20, pp. 625–634.)

New experimental records to support still further the authors' previous exposition of the difficulties in interpreting the shock breakdown of gases according to Townsend's theories (*cf* September Abstracts).

Die erste Aussenaufnahme einer Wanderwelle (The First External Record of a Wave-surge).—W. Rogowski and E. Flegler. (*Arch. f. Elektrot.*, 17th September, 1928, V. 20, pp. 635–636.)

The first oscillograms of a surge were published by the writers in 1925. They now show the progress made in the technique by giving photographs of such waves (taken by the external method) of 1/10,000th, 1/250,000th and about 1 millionth sec., finishing with one of about 0.4×10^{-6} sec., involving a recording speed of about 2,000 km./sec.

A Determination of a Limit of the Number of Free Electrons in a Metal.—F. E. Colpitts. (*Journ. Franklin Inst.*, October, 1928, V. 206, pp. 489–501.)

The lower limit of the number of free electrons in gold is found to be of the order of 2×10^{17} c.c., in tungsten 9×10^{15} c.c.

An Attempt to Detect a Magnetic Field as the Result of the Rotation of a Copper Sphere at High Speed.—W. F. G. Swann and A. Longacre. (*Journ. Franklin Inst.*, October, 1928, V. 206, pp. 421–434.)

Final report on the experiment mentioned in August Abstracts. So far as accounting for the earth's magnetic field is concerned, results were negative: but it is pointed out that a comparatively small change in the equation worked to would cause the value to come below the limit of sensitivity of the measuring apparatus, whereas it would be negligible in the case of the earth.

Théorie Moléculaire de la Diffusion de la Lumière par les Fluides (Molecular Theory of the Diffusion of Light by Fluids).—Y. Rocard. (*Ann. de Physique*, July-August, 1928, V. 10, pp. 116–179.)

The first thirty pages are occupied by a historical bibliography formed chiefly of abstracts with a running commentary. The rest of the paper develops the purely molecular theory, neglecting for the moment the inter-molecular field. In the following number (September-October, pp. 181–231) this field is taken into consideration.

Wave Mechanics and Radioactive Disintegration.—Gurney and Condon. (*Nature*, 22nd September, 1928, V. 122, p. 439.)

It has hitherto been necessary to postulate some special arbitrary "instability" of the nucleus of a disintegrating atom; but here it is pointed out that disintegration is a natural consequence of the laws of quantum mechanics without any special hypothesis. A recent and puzzling experimental result is explained by the same reasoning.

The Photo-electric Properties of Thin Films of the Alkali Metals.—N. R. Campbell. (*Phil. Mag.*, October, 1928, V. 6, pp. 633–648.)

The observations—mainly on thin films produced by depositing an alkali metal on some other material, driving it off by heat, and subjecting the remaining film to a discharge in hydrogen—would seem to have an important bearing upon attempts to correlate thermionic and photo-electric emission.

Mercury Lamp and Radium as Ionisers.—Rogowski and Tamm. (*Science Abstracts*, 25th September, 1928, V. 31A, p. 721.)

The mercury lamp produced the same result as 7 mgm. of radium at the same distance, as regards the effect on the potential required to produce a spark between metal electrodes in air.

Calcul du Champ Interne de Polarisation (Calculation of the Internal Field of Polarisation).—de Malleman. (*Comptes Rendus*, 24th September, 1928, V. 187, pp. 536–538.)

The writer describes a direct molecular method, applicable to any assemblage of molecules, in solid or fluid, isotropic or anisotropic, which avoids the difficulties and contradictions encountered when Lorentz' method (" Method of Cavities ") is applied to the calculation of electro-optical properties.

Electron Reflection. — S. Szczeniewski. (*Comptes Rendus*, 9th July, 1928, V. 187, pp. 106–109.)

The writer has set out to amplify the results of G. P. Thomson and Davisson and Germer by experiments on a more direct method, which measured the reflection of a Cathode ray by a cleavage-surface of a bismuth crystal, for three different values of accelerating potential and for different angles of incidence. Curves were plotted showing clearly the maxima corresponding to the different orders of reflection: the wavelengths calculated from the positions of these maxima agreed with those given by the formula of wave-mechanics.

The Character of the Discharge in an Air Gap submitted to a Steep-fronted Potential Wave.—Mochizuki and Murakami. (*Journ. I.E.E., Japan*, June, 1928, No. 479, pp. 652–661.)

The effect of ultra-violet light in the case of various forms of electrode is studied.

The Scattering of Positive Ions from a Platinum Surface.—R. W. Gurney. (*Phys. Review*, September, 1928, V. 32, pp. 467–477.)

The scattering from solid surfaces of particles of small momentum has been investigated by Davisson with Kunsman and Germer, who studied electrons; and by Ellett and Olson, who examined the slow atoms of cadmium, sodium and hydrogen. Here, the scattering of particles of comparatively high momentum is studied. The source used was an oxide catalyst emitting potassium, cæsium or lithium ions.

Temperature of the Cathode as a Factor in the Sputtering Process.—L. R. Ingersoll and L. O. Sordahl. (*Phys. Review*, October, 1928, V. 32, pp. 649–656.)

The Distribution of Electrons in a Metal.—J. E. Lennard-Jones and H. J. Woods. (*Proc. Roy. Soc.*, 1st October, 1928, V. 120a, pp. 727–735.)

The writers regard the metal as a whole, and find the average distribution of electrons in the same way that Thomas and Fermi have done for isolated atoms.

Sur l'État dit " Sama-Zustand " (The Condition called " Sama-condition ").—E. A. Holm. (*Comptes Rendus*, 24th September, 1928, V. 187, pp. 531–534.)

The writer produces experimental evidence of the existence of this phenomenon, which was foretold on theoretical grounds by Dallwitz-Wegner, namely, that gravity can produce, in the heart of a solid, liquid or gaseous body, an ascending thermal gradient.

The History and Recent Progress of the Theory of Electrons. — T. Shimizu. (*Journ. Jap. I.E.E.*, July, 1928, pp. 691–699.)

In this general survey the writer lays special stress on the relations between luminous waves and the mechanical oscillations of the electrons.

Motion of Electrons in Gases.—J. S. Townsend. (*Proc. Roy. Soc.*, 1st October, 1928, V. 120a, pp. 511–523.)

A detailed reply to Atkinson's criticisms of the author's previous results and conclusions (*see* September Abstracts).

The " Action " of an Electromagnetic Field.—S. R. Milner. (*Proc. Roy. Soc.*, 1st October, 1928, V. 120a, pp. 483–502.)

Advanced mathematical treatment leading to expressions for the Hamiltonian and Eulerian " actions " of the field which form strict equivalents to those for the actions of a dynamical system.

MISCELLANEOUS.

The Behaviour of Overhead Transmission Lines in High Winds.—E. H. Lamb. (*Journ. I.E.E.*, October, 1928, V. 66, pp. 1079–1085.)

Harmonic Production in Ferromagnetic Materials at Low Frequencies and Low Flux Densities.—E. Peterson. (*Bell Tech. Journ.*, October, 1928, V. 7, pp. 762–796.)

It has been established experimentally, as a confirmation of theoretical speculations, that the third harmonic E.M.F. generated by a sinusoidal wave of magnetising force may serve as an index of the distortion with a complex wave: this paper is devoted to an investigation of the third harmonic production in its dependence upon the properties of hysteresis loops.

Studien über Schwingungen von Kreisplatten und Ringen (The Vibration of Discs and Rings).—W. Hort and M. Koenig. (*Zeitschr. f. Tech. Phys.*, October, 1928, pp. 373–382.)

Theoretical treatment confirmed by experimental tests, of which photographic records are shown: mostly of discs with central aperture.

The Effect of Chemical Composition on the Sensitivity of Galena as a Radiodetector: and the Cold Emission from Crystals.—W. Ogawa, C. Nemoto, and S. Kaneko. (*Researches of Electrot. Lab., Tokio*, No. 230, June, 1928, 28 pages.)

The " Fultograph ": First Complete Description of the Picture Receiving Machine.—F. H. Haynes. (*Wireless World*, 24th October, 1928, V. 23, pp. 555–560.)

VI KONGRESS DER ASSOZIATION DER RUSSISCHEN PHYSIKER (VI Congress of the Assoc. of Russian Physicists).—M. Born. (*Naturwiss*, 28th September, 1928, pp. 741–743.)

A summary of the recent congress at Moscow.

HIGH ANGULAR VELOCITIES OBTAINED BY ROTORS HAVING NO SOLID AXIS.—E. Henriot and E. Huguenard. (*Journ. Franklin Inst.*, October, 1928, V. 206, pp. 561–562.)

Summary of a French article. Rotors supported by sheets of gas attained speeds of 11,000 r.p.s. (for diameter of 11.7 mm.), giving a peripheral speed of 404 m/sec. Small mirrors reduced the speed (by air-churning) to about 5,500 r.p.s., but even so the arrangement enables tests on the velocity of light to be made over distances as small as one metre. For further development see Lawrence, Beams and Garman, *Phys. Review*, No. 6, 1928. These workers obtain speeds of 5,000 to 6,000 r.p.s. for a diameter of 16 mm.

USE OF MEGGER CIRCUIT IN GEOPHYSICAL PROSPECTING. (*Journ. Franklin Inst.*, October 1928, V. 206, pp. 547–548.)

EXPERIMENTS IN UNDERGROUND COMMUNICATION THROUGH EARTH STRATA.—Ilsley, Freeman and Zellers. (*Science Abstracts, B*, 25th September, 1928, V. 31, p. 522.)

Summary of a paper from the Bureau of Mines on experiments to devise, if possible, practical means of communication with entombed miners.

LA NOUVELLE MÉTHODE LORENZ-KORN POUR LA TRANSMISSION DES IMAGES PAR LA T.S.F. (The new Lorenz-Korn method of Picture Telegraphy by Wireless).—(*Génie Civil*, 22nd September, 1928, V. 93, p. 290.)

A short paragraph based on Noack's article in *Zeitschr. des Vereines deutscher Ingenieure*, 14th April.

CONTRACTIONS FOR TITLES OF PERIODICALS.—Allan Gomme. (*Nature*, 22nd September, 1928, V. 122, p. 441.)

This reply to a letter (October Abstracts) defends the " World List " and its abbreviations.

WHAT DO THEY KNOW OF RADIO . . . ?—D'Orsay Bell. (*Wireless World*, 3rd October, 1928, V. 23, pp. 477–480.)

In the course of an article directing attention to various researches on parts of the Frequency Spectrum other than " radio," the author suggests that ultra-audible sound waves might have an effect—destructive, repulsive, or perhaps even attractive—on small insects such as mosquitoes.

HIGH FREQUENCY SOUND RADIATION FROM A DIAPHRAGM.—R. B. Lindsay. (*Phys. Review*, September, 1928, V. 32, pp. 515–519.)

By a hydrodynamical-acoustical method, a calculation is made of the intensity of the H.F. sound radiation from a circular piston-like oscillator, at a distance from the oscillator greater than twice the radius.

PROBLEMS IN POWER-LINE CARRIER TELEPHONY.—W. B. Wolfe and J. D. Sarros. (*Journ. Am. I.E.E.*, October, 1928, V. 47, pp. 727–731.)

The advantages of a new single-frequency, single side-band, carrier-suppressed system are described, together with an outline of this system. A discussion containing interesting points is summarised on p. 764.

POWER LINE CARRIER TELEPHONY.—L. F. Fuller and W. A. Tolson. (*Journ. Am. I.E.E.*, October, 1928, V. 47, pp. 711–715.)

Gives an outline of modern communication requirements in this field, the problems involved, and the different types of equipment now available. A discussion containing interesting points is summarised on p. 764.

AUSTRALIAN CARRIER SYSTEMS.—R. N. Partington. (*P.O. Elec. Eng. Journ.*, October, 1928, V. 21, pp. 215–223.)

PICTURE TELEGRAPHY.—(*P.O. Elec. Eng. Journ.*, October, 1928, V. 21, pp. 191–199.)

Deals with the Bell, Siemens-Carolus, and Belin systems: gives the Transmission Line Requirements for successful working, and describes certain difficulties encountered in trials of the Siemens system between London and Berlin, and the means of overcoming them.

DIE BERLINER FUNKSCHAU 1928 (The Berlin Radio Exhibition 1928).—H. Kröncke. (*Rad. f. Alle*, October, 1928, pp. 450–456.)

The writer picks out a few miscellaneous exhibits of special interest. These include a Loewe-v. Ardenne receiver in which three double valves are said to give a H.F. amplification of 5,000; a patented smoothing choke coil for rectified filament current, in which the energy of the fluctuations is almost entirely absorbed by a subsidiary winding short-circuited by a small incandescent lamp; a receiver in which loud-speaker or telephones are replaced by a small wooden rod intended to be held between the teeth to enable deaf people to enjoy broadcasting; and (with a certain reservation) a cylindrical " earth-antenna " said to give good summer and winter reception of the " pure ground wave " when buried only 75 centimetres deep.

BILDFUNK UND FERNSEHEN AUF DER 5 DEUTSCHEN FUNKSCHAU (Picture Wireless and Television at the 5th German Radio Exhibition.)—H. Kröncke. (*Rad. f. Alle*, October, 1928, p. 463–464.)

A brief survey of the exhibits, and the conclusions drawn by the writer.

UNE NOUVELLE APPLICATION DES COURANTS DE HAUTE FRÉQUENCE (A new Application of H.F. Currents).—Bordier. (*Comptes Rendus*, 15th October, 1928, V. 187, pp. 687–688.)

A new form of d'Arsonvalisation (the medical use of H.F. currents) by which medicinal substances such as cocaine, iodine, or aconite are caused to be absorbed by the skin or mucous membrane. Such absorption has been obtained before by constant current, but in this case decomposition of the molecule takes place and there is moreover the danger of ultra-violet radiation. Both these factors are removed by the use of H.F. combined with a special electrode without any metallic point.

Aus der Grossen Deutschen Funkausstellung (From the great German Radio Exhibition).—W. Burstyn. (*E.T.Z.*, 11th October, 1928, pp. 1504–1507.)

Acoustics.—A. G. Huntley. (*Journ. R.S. of Arts*, 12th October, 1928, V. 76, pp. 1146–1158.)

Cantor Lecture of 16th April, on the acoustics of buildings.

Das Problem der Photo-telephonie (The Problem of Telephony by Light-Rays).—K. Zickler. (*Elektrot. u. Masch. bau.*, No. 29, 1928, V. 46, pp. 769–775.)

A new and effective method is described and the whole problem placed on a quantitative basis.

Über ein optische Interferenzmethode zur Untersuchung von Membranen (An optical interference method of investigating diaphragms).—P. Paasche. (*Zeitschr. f. Tech. Phys.*, October, 1928, pp. 411–414.)

Description of a stroboscopic interferometer method for measuring the deflections of electrically excited vibrating diaphragms. Records are shown of resonance and time-amplitude curves.

Über neuere Akustische und Insbesondere Elektroakustische Arbeiten (Latest work on Acoustics, and in particular Electro-acoustics).—F. Trendelenburg. (*See* under "Measurements and Standards.")

Some Fundamental Definitions.—R. A. Wilmotte. (*E.W. & W.E.*, November, 1928, V. 5, pp. 607–615.)

On the Computation of Induced Voltage in a Communication Line caused by Occasional Grounding of a Neighbouring Power Line.—K. Kanaya. (*Journ. I.E.E. of Japan*, August 1928, pp. 856–867.)

Chauffage par Induction (Heating by Induction).—P. Bunet. (*Bull. d.l. Soc. Fran. d. Élec.*, September, 1928, V. 8, pp. 940–992.)

An important paper on the theory of induction furnaces (condenser discharge or alternator) and its application in practice. A preceding paper by Dufour (pp. 929–939) discusses various forms of spark dischargers for such furnaces.

Mitteilung zum Detektorproblem: der Elektrolytische Detektor (The Detector Problem: the electrolytic detector).—G. G Reissaus. (*Phys. Zeitschr.*, 15th September 1928, pp. 655–658.)

Esperanto Section.

Abstracts of the Technical Articles in Our Last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en Nia Lasta Numero.

ATMOSFERAĴOJ.

Nuna Stato de Scio pri Atmosferaĵoj.

Resumo de prelego de S-ro. R. A. Watson Watt, B.Sc., F.Inst.P., A.M.I.E.E., legita antaŭ Sekcio A, de la Brita Asocia Kunveno ĉe Glasgow, Septembro, 1928a.

La prelego konsideras la temon laŭ vidpunkto de donitaĵoj koncernantaj la atmosferajojn mem. La aŭtoro priskribas la rezultojn de laboro pri l'ondoformo de atmosferaĵoj (kiel determinitaj de observadoj pri la katodradia oscilografo); numera incideco de atmosferaĵoj; direktaj observadoj—kaj ĉe mezaj fluoj kiel determinitaj de rotacianta radia anteno kaj pluma registrilo, kaj ĉe individuaj atmosferaĵoj, kiel ekzamenitaj de l'katodradia direktotrova sistemo; la intenseco de l'perturbo, kaj la amplekso de atmosferaĵoj, kiel determinitaj de vasta brodkasta ekzperimento.

Bilda tabelo montras la ĉefajn formojn de atmosferaĵoj viditajn en Anglujo, dum komparoj estas ankaŭ donitaj pri la ĉefaj formoj observitaj en Anglujo, Khartoum, kaj Okcidenta Aŭstralio.

La direktaj observadoj ŝajnas esti de konsiderinda meteorologia intereso, kaj donas multe da informo pri la distribuado de fulmotondra aktiveco.

PROPRECOJ DE CIRKVITOJ.

Metodo por Kalibri Malaltfrekvencan Valvan Generatoron per Unuobla Frekvenca Norma Fonto.—T. S. Rangachari.

La metodo konsistas laŭjene; kunigi unue la konatan kaj poste la nekonatan fonton trans cirkvito de variebla rezisteco R laŭserie kun indukteco de konata rezisteco R_L. La norma fonto estas aplikita kaj R alĝustigita al valoro R_1, kiam la voltkvanto trans ĝi egalas tiun trans la indukteco (mezurita per termiona voltmetro). La nekonata fonto estas poste anstataŭigita kaj R alĝustigita al nova valoro R_2 por simila egaligo kiam

$$f_2 = f_1 \times \frac{R_2^2 - R_1^2}{R_1^2 - R_L^2}$$

Notoj estas donitaj pri praktikaj punktoj en la

metodo, kaj rezultoj estas montritaj en tabelo kaj kurvoj.

Ŝveladoj en Eliminilaj Glatigaj Cirkvitoj.—A. G. Warren.

La aŭtoro diskutas la ŝveladojn, kiuj emas okazi kiam ia ŝanĝo okazas en la altatensia voltkvanto aplikita al ricevilo pere de glatiga cirkvito. Ĉi tiuj ŝveladoj povas esti multe pli ol normala potencialo kaj kaŭzi riskon de paneo.

La ŝveladoj estas pli seriozaj je enŝalto aŭ malŝalto, aparte se la valvoj ne brulas.

Por sufiĉa glatigo, LC'a (Indukteco-Kondensatora) produto de ĉirkaŭ 200 mikrofaradoj-henrioj estas dezirinda. Oni montras, ke glatiga cirkvito, kiu povas esti perfekta ĉe unu instrumento, povas naski malbonajn ŝveladojn ĉe alia. Por instrumento, kiu bezonas definitivan anodan kurenton, oni montras, ke malpliigante la grandecon de la kondensatoroj kaj pliigante la valoron de l'ŝokbobeno, malpliigas la ŝveladon je enŝalto, sed pliigas la ŝveladon je malŝalto, kaj inverse. Estas do optimumaj valoroj por ĉi tiuj komponeroj, kaj oni citas regulojn por ebligi, ke kondensatoroj kaj ŝokbobeno estu dimensiigitaj laŭ la ŝarĝo, tiel ke la normala funkcia voltkvanto ne estas superita, aŭ je enŝalto aŭ malŝalto.

HELPA APARATO.

Portebla Oscilografa Ekipaĵo por la Observado de Efemera Elektra Fenomenaro.—P. R. Coursey.

La aparato priskribita estas la plej lasta modelo de la tri-elementa oscilografo de la *Cambridge Instrument Company*, kun modifaĵoj je la kunmeto por la aparta celo skizita. La ĝenerala aranĝo de la instrumento estas unue priskribita, inkluzive la metodo por ekspozi fotografan filmon por registro de l'onda formo.

La normalaj aranĝoj ne estas bone adaptitaj por la registrigo de efemeraĵo, kies ĝusta tempo de okazo estas preter la kontrolo de l'funkciisto, kaj la modifaĵoj priskribitaj estas desegnitaj por faciligi ĉi tion. La kamera cilindro estas rotaciata senĉese, kaj la obturatoro malfermita dum antaŭdeterminita tempo, por enhavi la efemeraĵon registritan. Nebuliĝo de l'filmo estas malhelpita de vertikala vergo, kiu obstrukcias la nedefleksitan radion for de la vibrila spegulo. Detaloj de l'modifaĵoj por ĉi tiu celo estas donitaj, kaj de l'metodo de tempo-registrado. La tuta aparato estas kunmetita sur rulportilo pro portebleco, kaj sistemo de rektifikatoroj estas provizita por funkciigi la kontinukurentan motoron per alternkurenta provizo.

La artikolo estas ilustrita de fotografaĵoj de l'kunmetado kaj diagramoj de ŝuntaj aranĝoj, rektifikatoroj, k.t.p.

GENERALAJ FIZIKAJ ARTIKOLOJ.

Kelkaj Fundamentaj Difinoj.—R. M. Wilmotte.

Ĉi tiu artikolo diskutas redakciajn artikolojn (en marta kaj aprila numeroj) pri la malfacilaĵoj kuŝantaj sub la ordinaraj signifoj de P.D. (potenciala diferenco) kaj E.M.F. (elektromova forto) en alternkurentaj cirkvitoj, kaj poste diskutas ĉi tiujn iomlonge kaj laŭ iomete malsama vidpunkto. La difinoj tiel obtenitaj estas poste etenditaj al aliaj kvantoj.

Ellaborante la rezonadon de l'originalaj redakciaj artikoloj, la aŭtoro difinas skalajn kaj vektorajn potencialojn ; poste pasas al elektra intenseco kaj al difinoj kaj distingoj de P.D. kaj E.M.F., kun la ilustraĵo de l'fermita kadro. La rezonado estas poste etendita al la konsiderado pri impedanco, uzante la difinon de reaktanco kiel bazon por la plua ekzameno de indukteco kaj kapacito. La ekzemploj de mem-indukteco kaj de komuna indukteco estas pritraktitaj ; poste la aŭtoro pasas al kondukeco kaj delokigaj kurentoj, kondukante al difino de kapacito. Distribuitaj indukteco kaj kapacito estas laste konsideritaj.

La rezonado tratute estas laŭ matematika bazo, kaj oni donas esprimojn por la diversaj difinoj atingitaj.

Redakcia artikolo diskutas la rezonadon de S-ro. Wilmotte.

DIVERSAĴOJ.

Resumoj kaj Aludoj.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato), kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

Libro-Recenzoj.

Recenzoj estas donitaj pri la jenaj verkoj :—

Letters Patent for Invention (Patentaj Dokumentoj por Inventado), de A. W. Griffiths, B.Sc., Advokato.

Experimental Radio (Eksperimenta Radio), de R. R. Ramsay, Ph.D. (tria eldono).

Sciencaj Instrumentoj ĉe Olympia. Revuo pri kelkaj aparatoj interesaj laŭ laboreja vidpunkto ĉe la lastatempa Radio-Ekspozicio (Londono).

La Ekspozicio estis ĉefe de brodkasta intereso kun kompare malmulto interesa laŭ laboreja vidpunkto pri altfrekvencaj kurentoj. Raporto estas donita en ĉi tiu artikolo pri diversaj mezuraj instrumentoj, ondometroj, k.t.p.

Kontinukurentaj instrumentoj pritraktitaj enhavas tiujn de Ernest Turner, S-roj. Ferranti Ltd., la “ Avometer ” de l'Aŭtomatic Coil Winder Company, S-roj. A. H. Hunt, kaj S-roj. Siemens Brothers. Alternkurentaj kaj alternfrekvencaj instrumentoj de Ernest Turner kaj S-roj. Ferranti estas ankaŭ pritraktitaj, la ĉi-lasta enhavanta alternkurentan instrumenton konsistantan el ordinara kontinukurenta funkcimetodo, kune kun ponto de kvar kuproksidaj rektifikatoroj.

La ondometroj revuitaj enhavas modelojn de S-roj. Burndept, S-roj. Bowyer-Lowe, la Igranic Company, kaj S-roj. Dubilier, kiuj ankaŭ montris grandan aron da normaj kondensatoroj por laboreja laborado, kaj instrumenton kondensatore-ŝuntitan por grandaj radio-frekvencaj kurentoj.

Instrumentoj por provi valvojn de S-roj. Ferranti kaj de S-roj. R. I. kaj Varley estas ankaŭ priskribitaj, dum la fako pri aliaj elmontraĵoj traktas pri novaj transformatoroj, valvoj, kaj la nova Aŭtomata Alarma Ekipaĵo de S-roj. Siemens Brothers.

La artikolo estas bone ilustrita per fotografaĵoj de multaj elmontraĵoj priskribitaj.

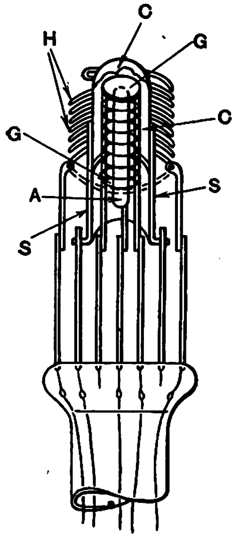
Some Recent Patents.

The following abstracts are prepared with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each.

INDIRECTLY-HEATED VALVES.

(*Application date 23rd June,* 1927. *No.* 297495.)

Relates to valves of the kind in which an electron-emitting filament is heated by radiation from a special heating element fed directly from the electric-light mains. According to the invention, the normal arrangement of the several valve electrodes is inverted. For instance, a central anode *A*, in the form of a thin metal tube, is surrounded by a special grid *G*, outside which comes a tubular cathode *C*, and finally an external winding *H* of carbon or tungsten wire which serves as the heating element.



The tubular cathode *C* is coated with alkaline-earth oxides and is closed at the upper end. At the lower end it extends downwards to form a screen *S*, which shields the grid and anode from the heat of the windings *H*. The top of the grid is also closed in. As the heating element *H* is connected directly to the mains, it must be of considerable length in order to have a resistance adequate to the normal domestic supply voltages. By locating it outside the other electrodes a more robust and compact arrangement than usual is ensured.

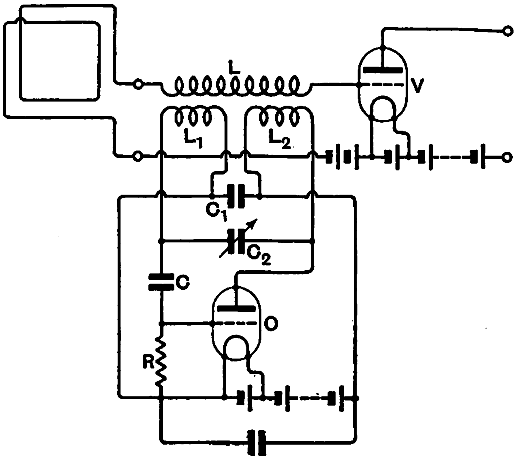
Patent issued to The M.–O. Valve Co., Ltd.

SUPERSONIC RECEIVERS.

(*Application date,* 24*th June,* 1927. *No.* 297507.)

In general the voltage induced into the coupling-coil *L* from the local oscillator *O* of a supersonic set is not uniform over a wide range of frequencies, but increases for the higher and diminishes at the lower frequencies. This gives rise to excessive noise in the one case and to ineffective detection in the other, after the beat note has passed through the first detector *V* and the signal components have been finally separated.

To remove this defect the local oscillator *O* is provided with a grid condenser *C* of 0.005 mfd. and a resistance *R* of approximately 12,000 ohms. The oscillator coils L_1, L_2 are separated by a blocking condenser C_1, whilst the circuit as a whole is tuned to the operating frequency by a condenser C_2. The effect of the grid leak and condenser *R*, *C* is to damp the main oscillatory circuit *C* to a greater extent at high frequencies than at low, thus counterbalancing the effect of the variable coupling previously mentioned, and maintaining a constant energy-transfer from the oscillator *O* to the first detector *Y* at all settings of the tuning condenser C_2.

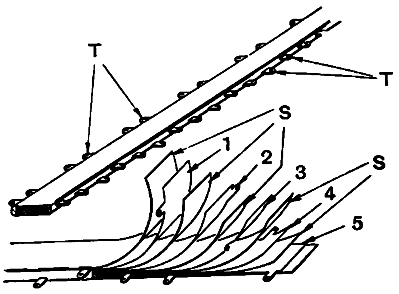


Patent issued to Standard Telephones and Cables, Ltd.

WIRING SYSTEMS.

(*Convention date* (*U.S.A.*), 10*th August,* 1926, *No.* 275938.)

A multiple wiring element is built up of a number of flat metal conductors 1 . . . 5 interleaved with strips *S* of insulating material. Metal tabs *T* are attached to each conductor at intervals, and project outwards to facilitate connection to the various circuit components when wiring-up the set. The insulating strips, in combination with the conductors, form a condenser system which is utilised to replace the ordinary fixed by-pass con-



densers for shunting high-frequency currents across the batteries or other impedances on the low-frequency side of the receiver. Also the outer metal strips serve to screen the inner conductors and so prevent undesirable feed-back and pick-up effects.

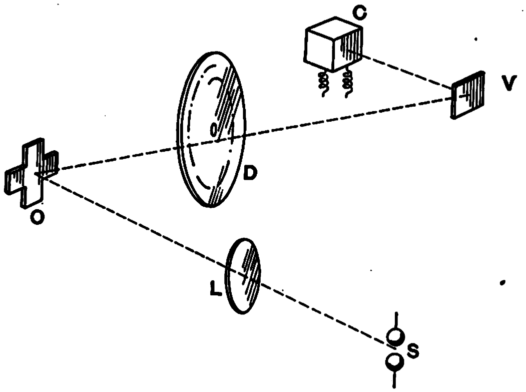
Patent issued to E. T. Flewelling.

TELEVISION SYSTEMS.

(*Application date 10th March*, 1927. *No.* 297014.)

In his early experiments with ether waves, Hertz showed that such waves could be detected by the sparks induced between two or more conductors separated by a very small gap. The present invention proposes to utilise this effect for the purpose of transmitting a visible image of a normally invisible object. The object, shown in the form of a cross *O*, is first explored by a stream of short-wave energy generated at *S*.

The generated energy is stated to be of the same order as the infra-red part of the spectrum, but of slightly longer wavelength than the infra-red rays. This "invisible light" is focussed on the object *O* by means of a lens *L* of sulphur or bitumen. The reflected rays are passed through a rotary "scanning disc" *D* and are then thrown on to a viewing screen *V*. This operates on the principle of the Hertzian detector mentioned above, its surface being composed of separated conducting particles, such as a sprinkling of metal powder on a plate of non-conducting material. Instead of viewing the image so produced directly, the resultant "sparks" may be thrown upon a light-sensitive cell *C*, which in combination with known mechanism serves to reproduce the image at a distance.



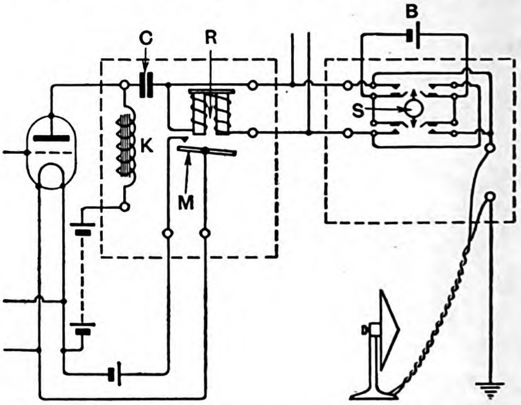
Patent issued to Television Ltd., and J. L. Baird.

REMOTE CONTROL SYSTEMS.

(*Application date, 2nd August*, 1927. *No.* 297918.)

A receiving set *S* is switched on or off by means of a polarised relay *R* controlled from the distant point by a switch *S*. A choke *K* diverts the steady current from the connecting leads, so that musical frequencies alone flow through the loud speaker, which is earthed as shown. A blocking condenser *C* keeps the H.T. voltage off the leads. The moving arms of the double-pole reversing switch *S* are bridged by a single dry-cell battery *B*, which is normally kept out of circuit and only comes into operation momentarily.

When the switch *S* is thrown upwards, a pulse of current from the battery B flows in one direction through the relay *R*, to close the contact *M* and so light the valve filaments. Throwing the switch downwards will reverse the direction of the momentary flow of current from the battery *B* through the relay *R*, and thus trip the polarised armature to break the filament circuit.

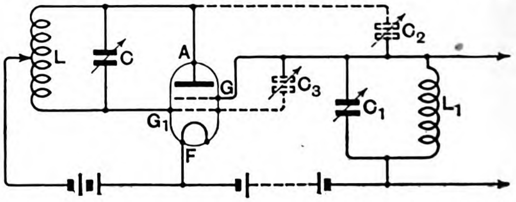


Patent issued to F. S. Angel.

A STABILISED TETRODE CIRCUIT.

(*Application date 8th June*, 1927. *No.* 296806.)

Inter-electrode capacity is neutralised in a four-electrode valve amplifier by connecting the input circuit *L*, *C* across the anode *A* and inner grid G_1, with a variable tapping to the filament, whilst the output circuit L_1, C_1 is connected between the outer grid *G* and the filament as shown. Any capacity coupling between the anode *A* and the outer grid *G* is effectively offset by the coupling between the outer and inner grids *G*, G_1. For slight departures from complete neutralisation, the amplifier can be brought to the desired condition by adjustment of the filament current. If necessary a small external condenser is connected in parallel with the lesser inter-electrode capacity, as at C_2 or C_3. In the latter case the tapping point on the input coil *L* may be moved farther towards the top so as to throw a larger proportion of the input voltage on the inner grid G_1, thus increasing the efficiency of the amplifier.

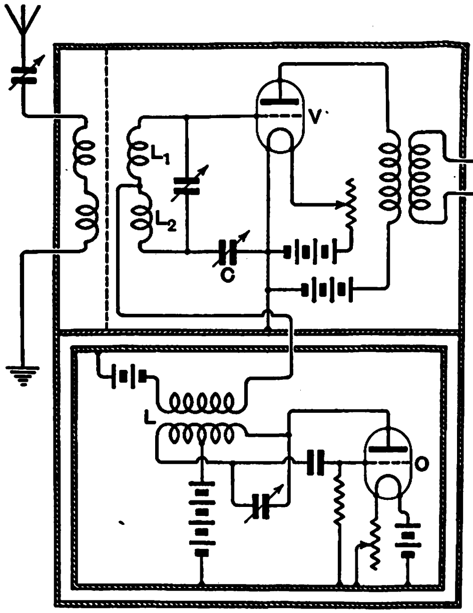


Patent issued to E. W. B. Gill and R. H. Donaldson.

PREVENTING RE-RADIATION.

(*Convention date* (*U.S.A.*), 23*rd May*, 1927. *No.* 291012.)

In a heterodyne or supersonic receiver, the energy from the local source of oscillation is liable to be communicated to the aerial, and so cause local disturbance by re-radiation. In order to prevent this effect the current from the local oscillator O is applied through a coupling L to the mid-point of the input circuit of the detector valve V so that it divides and flows equally in opposite directions through the coils L_1, L_2. No transfer to the aerial can therefore occur.



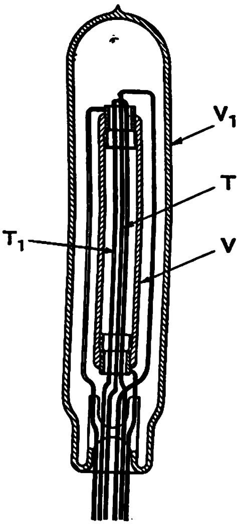
Signal energy transferred from the aerial flows through the coils L_1, L_2 in series so that the full potential fluctuations are applied across the grid and filament. A condenser C equal to the inherent grid-to-filament capacity is inserted in the filament lead, as shown, so that its reactance upsets the balance of the virtual Wheatstone-bridge arrangement sufficiently to enable the effect of the local oscillations from O to reach the grid. Here they combine with the incoming signals to form the desired beat frequency. The oscillator O is housed inside a double copper shield. In the case of supersonic reception, the intermediate frequencies are further amplified at A.

Patent issued to Marconi's Wireless Telegraph Co., Ltd.

PHOTO-ELECTRIC CELLS.

(*Convention date* (*U.S.A.*), 8*th June*, 1927. *No.* 291763.)

It is usual to deposit a thin film of light-sensitive material, such as alkali metal, on the inside of an evacuated glass vessel, leaving a transparent window through which the activating beam of light can be admitted. In course of time, however, the alkali coating tends to volatilise, and to be redeposited over the transparent area, so as to obscure the window aperture and thus lessen the sensitivity of the cell as a whole.



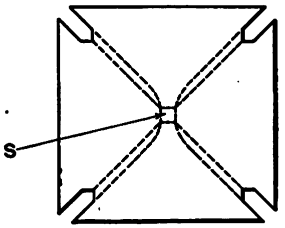
In order to remove this effect the light-sensitive coating is made of a composite layer. For instance, a coating of tungsten or molybdenum having a low vapour pressure is first deposited, upon which a photo-sensitive coating of alkali is superposed, the double layer being so thin that it is transparent to light. In manufacture a filament T of tungsten and another T_1 of platinum coated with an alkali metal salt are mounted inside an inner tube V, and the whole is then enclosed in an outer tube V_1. Each filament is heated in turn to a temperature sufficient to vaporise first the tungsten and then the alkali, and so to deposit layers of the required thickness on the inside walls of the tube V.

Patent issued to Westinghouse Electric and Manufacturing Co., Ltd.

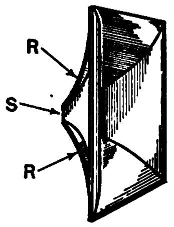
LOUD SPEAKER DIAPHRAGMS.

(*Application date* 14*th May*, 1927. *No.* 297131.)

A single piece of homogeneous material is cut and creased so as to form a number of curved surfaces of approximately pyramidal formation, and so that no additional material is required to make the joints air-tight. In operation the various flexed surfaces vibrate in unison along transverse straight lines, transmitting the sound energy to the surrounding air in the form of concentric polygons. Bodily or piston-like vibration is minimised, since the joints between the various flexed portions are only semi-rigid. The absence of stiffening or other extraneous material at the joints prevents damping and increases the overall efficiency of response.



(a)



(b)

The square piece of material is first cut at the corners and is then creased or scored diagonally as shown in dotted lines in Figure (a). When the blank is folded along the straight crease-lines, flexed backwards, and then folded along the curved crease-lines, with the material between the crease-lines overlapped upon the plain quadrants, the diaphragm assumes the pyramidal form shown in Figure (b) with four strengthening ribs *R* radiating from the central squares to which the vibrations from the magnetic movement are applied.

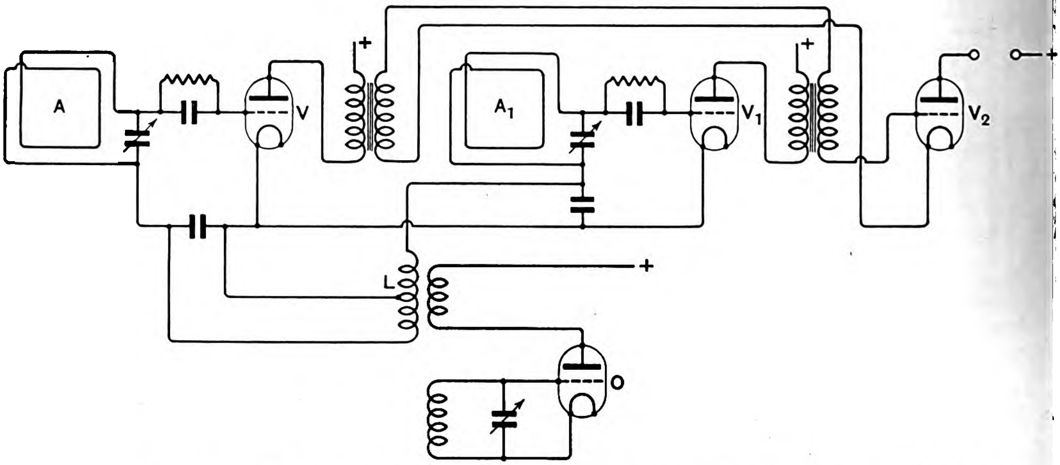
Patent issued to B. F. Waddell.

PREVENTING FADING EFFECTS.

(*Application date 12th April,* 1927. *No.* 297015.)

Signal waves are usually radiated from a transmitting station with the electric and magnetic vectors located in well-defined directions, *i.e.*, in definite planes of polarisation. Owing, however, to variable atmospheric and like conditions, the waves usually arrive at the receiving station polarised in different and conflicting planes. In such circumstances signals received on an ordinary aerial system will fluctuate in strength.

Accordingly, the receiving station is fitted with two or more aerials or loops, located in different planes, and means are provided for combining each aerial with the receiving apparatus in rapid succession, each alternation lasting for a very small interval of time, with the object of ensuring a constant overall signal strength. As shown in the Figure, the two aerials A, A_1 are set at right angles, and are coupled to valves V and V_1 respectively, the output circuit of both valves feeding a common amplifier V_2. A local oscillator valve O is tuned to any frequency from 50 to 100,000, and induces voltages into a coil L so that the grid potentials on the valves V, V_1 are varied in opposite senses at that frequency. The valves are thereby thrown alternately in and out of action, and thus connect the aerials A, A_1 in rapid succession to the receiving apparatus.

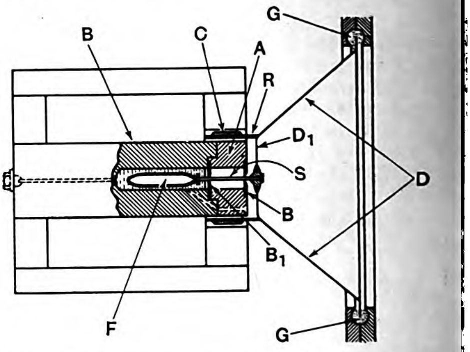


Patent issued to J. Robinson.

LOUD SPEAKERS.

(*Application date, 21st July,* 1927. *No.* 297183.)

In a moving-coil or other loud speaker certain of the moving parts of the magnetic driving-means are supported in a fluid, such as machine oil.



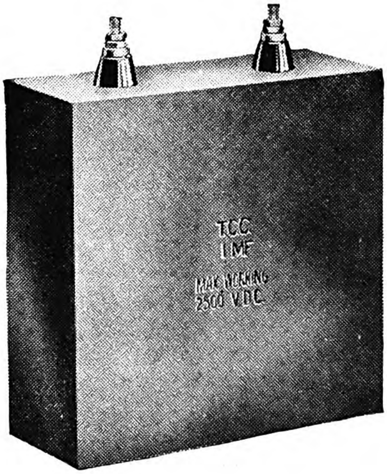
The core of the pot-magnet is made in two parts, an upper portion A and a lower B, both being bored out centrally to form a chamber for the fluid as shown. Bearing-discs B, B_1, say of vulcanised fibre, are fitted on the upper and lower ends of the part A, and have a central hole to guide the moving spindle S.

The conical diaphragm D is closed at the lower end by a disc D_1 to which is fixed a supporting ring R for the moving coil C. The outer edges of the diaphragm are housed in a groove G formed in the sounding-board. The groove is preferably filled with cotton-wool or velvet which, whilst having no appreciable effect on the diaphragm movement, prevents the air waves passing from one side of the diaphragm to the other. The spindle S is secured to a boss on the disc D_1, and carries at its lower end a float F, which is immersed in the liquid. In assembling the speaker machine oil is poured into the central chamber until the float F raises the lower end of the diaphragm clear of the part A, when the upper edge of the diaphragm will lie centrally in the groove G.

Patent issued to The British Thomson-Houston Co., Ltd., and G. R. Searle.

T.C.C.

SMOOTHING CONDENSERS



Because of their unfailing reliability "T.C.C." high voltage Smoothing Condensers are universally used by transmitters and experimenters, who must have a first-class component in which to place their confidence.

"T.C.C." Condensers will not let you down at the critical moment—they are built to give years of continuous service. Below is a list of standard capacities in three different voltages—these are kept in stock. Paper Condensers can be supplied for working up to 20,000 volts.

Condensers for Maximum Working Voltage of 800 Peak Value. (Tested 1500 V.D.C.)

CAP. MFD.	s.	d.	CAP. MFD.	s.	d.
1	7	6	5	24	6
2	10	0	6	28	6
4	19	4			

Condensers for Maximum Working Voltage of 1500 Peak Value. (Tested 2500 V.D.C.)

CAP. MFD.	s.	d.	CAP. MFD.	s.	d.
·5	8	0	2	15	2
1	10	0	4	28	6

Condensers for Maximum Working Voltage of 2500 Peak Value. (Tested 5000 V.D.C.)

1 mfd.	£1	8	0
2 mfd.	£2	10	0
4 mfd.	£4	17	6

THE TELEGRAPH CONDENSER CO., LTD., WALES FARM ROAD, NORTH ACTON, LONDON, W.3.

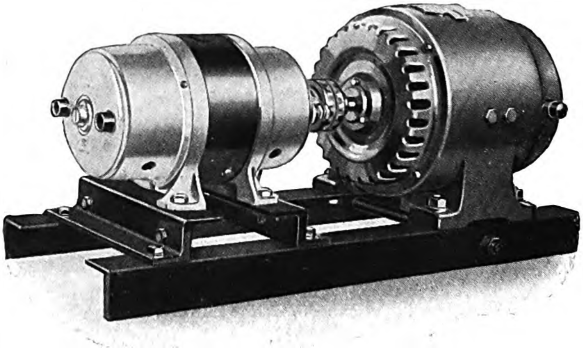
6447

M-L

GOOD RECEPTION

MEANS

MORE POWER.



A regular and permanent H.T. and L.T. supply is only possible by the use of a machine.

Send for particulars of the M-L Anode Converters, Rotary Transformers and Motor Generator Sets.

All prices now reduced.

M-L MAGNETO SYND. LTD., Radio Dept., COVENTRY.

For the real Radio enthusiast

Not radio products of mushroom growth—not cheap, unreliable components, but real engineering jobs, the outcome of years of specialised experience.

R.I. and Varley products have built up a reputation for QUALITY in every corner of the British Isles, and the real radio enthusiast, whether he is interested in receiving or transmitting apparatus, will find just what he requires in this new season's R.I. and Varley products.

HEAVY DUTY POWER TRANSFORMER.

For Low Power Transmitters or Super Power Amplifiers.
Input 200-220-240 Volts.
Output 375-0-375 Volts 110 m.a., centre tapped.
" 7·5 Volts 3·5 amps., centre tapped.
" 5·5 Volts 3 amps., centre tapped.

£3 . 10 . 0

ADJUSTABLE HEAVY DUTY CHOKE.

For use in Amplifiers where exceptionally heavy D.C. current is employed. As a smoothing choke for eliminator circuits where particularly large current is required it is the ideal component.
40/15 Henries, 0/200 milliamperes (Air gap adjustment screwed right in).
27/23 Henries, 0/200 milliamperes (Air gap adjustment screwed right out)

£2 . 5 . 0

TEN-WATT POWER RESISTANCES.

Constructed on a new semi-vitreous principle, which allows for expansion and contraction without liability of breakdown in insulation between adjacent sections of the winding. Accurate to within 5%. they have an area actually in excess of that required for their rated capacity.
They are designed to fit our standard universal holder, but it is recommended that they be fixed vertically rather than horizontally.
Complete range up to 100,000 ohms. Prices from

6/6 to 8/6.

RI AND Varley LTD.

THE MARK OF BETTER RADIO

Kingsway Hse., 103 Kingsway, London, W.C.2 Telephone : : : Holborn 5303

Kindly mention "Experimental Wireless" when replying to advertisers.

EXPERIMENTERS

to secure consistently accurate results experimenters must use only dependable components—*naturally* . . . to ensure, at the same time, the greatest degree of efficiency, they use Dubilier components—*necessarily* . . . for Dubilier components are the recognised criterion of invariable efficiency.

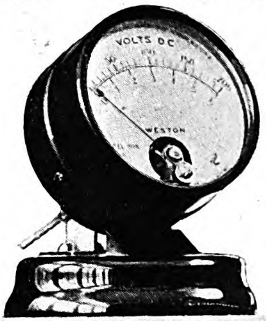
DUBILIER CONDENSERS

DUBILIER REGISTERED TRADE MARK

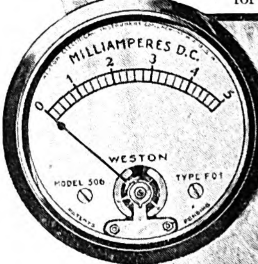
Advt. of Dubilier Condenser Co. (1925) Ltd., Ducon Works, Victoria Road, North Acton, W.3.

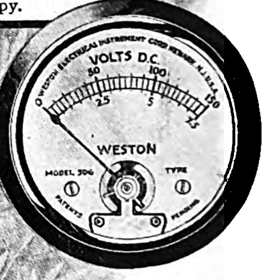
189

Weston sets the world's standard



Price: £2.10.0.
Model 506 Pin Jack Voltmeter with High Range Stand, measures High and Low Tension Voltages. The Weston free booklet "Radio Control" explains the uses of this and other Weston Radio Instruments. Write for your copy.





Model 506 Mil-Ammeter should be placed in the H.T. circuit of the valve to ensure correct operation and check distortion. Panel mounting type.
Prices: £1.15.0. £2.15.0.

Model 506 Panel Voltmeters ensure permanent accuracy. With a high internal resistance of 125 ohms per volt, they make practically no load on the batteries. Neat and compact.
Prices: £1.15.0. £2.15.0.

Model 489 Double Range D.C. Voltmeter is a necessary portable testing instrument for every Radio enthusiast. It is of great use in tracing circuit troubles. Made in various ranges with different sensitivities. Similar instrument for A.C. model 528.
Prices: £4.0.0, £7.12.0

WESTON ELECTRICAL INSTRUMENT Co. Ltd.,
15, GREAT SAFFRON HILL, LONDON, E.C.1.

EXPERIMENTAL WIRELESS
and The WIRELESS ENGINEER
A Journal of Radio Research and Progress

Technical Editor:
Prof. G. W. O. HOWE
D.Sc., M.I.E.E.

Editor:
HUGH S. POCOCK.

Assistant Editor:
F. H. HAYNES.

VOL. V. No. 63. DECEMBER, 1928. MONTHLY.

CONTENTS of THIS ISSUE

PAGE
EDITORIALS 657
THE GRAPHICAL ESTIMATION OF LOW-FREQUENCY CHOKE AMPLIFIER PERFORMANCE. BY W. A. BARCLAY, M.A. 660
THE WASHINGTON INTERNATIONAL RADIOTELEGRAPHIC CONVENTION OF 1927, I.E.E. WIRELESS SECTION CHAIRMAN'S INAUGURAL ADDRESS 666
A DOUBLE SUPER-HETERODYNE. BY J. F. RAMSAY 669
A NOTE ON SOME INTERFERING OSCILLATIONS EXPERIENCED IN A SUPERSONIC-HETERODYNE RECEIVER. BY R. L. SMITH-ROSE, D.SC., PH.D., A.M.I.E.E. 673
THE EFFECT OF FREQUENCY ON THE VALUE OF HIGH RESISTANCES OF THE GRID LEAK TYPE. BY W. JACKSON, M.SC. 677
CORRESPONDENCE 680
ABSTRACTS AND REFERENCES 683
ESPERANTO SECTION 695
SOME RECENT PATENTS 697
GENERAL INDEX TO ARTICLES, AUTHORS AND ABSTRACTS IN VOL. V., JANUARY-DECEMBER, 1928

The Editor is always prepared to consider suitable articles with a view to publication. MSS. should be addressed to the Editor, "Experimental Wireless and the Wireless Engineer," Dorset House, Tudor St., London, E.C.4. Especial care should be taken as to the legibility of MSS. including mathematical work.

Published Monthly, on the first of each month.

Editorial Offices:
116-117, FLEET STREET, LONDON, E.C.4.
Telephone: City 9472 (5 lines).

Advertising and Publishing Offices:
DORSET HOUSE, TUDOR STREET, LONDON, E.C.4.
Telegrams: "Experiwyr Fleet London."
Telephone: City 2847 (13 lines).

BIRMINGHAM: Guildhall Buildings, Navigation Street.
Telegrams: "Autopress, Birmingham."
Telephone: 2970 and 2971 Midland.

MANCHESTER: 260, Deansgate.
Telegrams: "Iliffe, Manchester."
Telephone: 8970 City (4 lines).

COVENTRY: Hertford Street.
Telegrams: "Cyclist, Coventry."
Telephone: 5210 Coventry.

SUBSCRIPTIONS:
Home and Abroad: One Year, 32/-: 6 Months, 16/-: Single Copies, 2/8 post free.

AMATEUR TRANSMITTERS

are reminded of the new regulations of the

INTERNATIONAL RADIO TELEGRAPH CONVENTION

which will come into force on

JANUARY 1st, 1929.

PIEZO-ELECTRIC RESONATORS

are the most accurate and convenient means of

STANDARDISING AND CALIBRATING ALL TYPES OF WAVEMETERS.

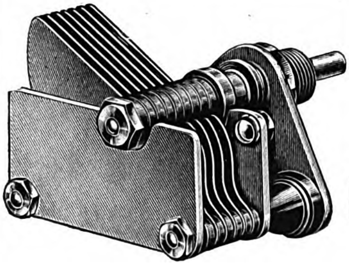
Methods of standardising and calibrating wavemeters from resonators are described in one of our publications which may be had free on request. In addition to the resonators therein listed we can now offer resonators to operate on wavelengths for use on the 42·6—41·3 and 172·3—152·2 bands as below:—

In dust-proof mounting ready for insertion in circuit:

Wavelength in meters.	Response frequency in kilo-cycles per sec.	Price (mounted).
Between 172·3 and 152·2	Between 1,740 and 1,970	£3 10 0
Between 42·6 and 41·3	Between 7,050 and 7,250	£3 10 0

National Physical Laboratory Certificate £1 1s. 0d. extra for each response frequency certified.

ADAM HILGER LTD., 24 Rochester Place, LONDON, N.W.1



"MITE" CONDENSER

PRICES REDUCED

The demand for our "Mite" Condenser has enabled us to effect an all-round reduction of prices. This is a splendid little line made on the same principle as our larger Condensers—extremely low loss: fitted with ball-bearing spindle. Smooth, free-from-backlash action. Supplied with or without dial.

NEW PRICES

Cap.	With Dial.	Less Dial.	Vernier.
·0005	7/6	6/6	10/–
·0003	7/–	6/–	9/6
·0002	6/6	5/6	9/–

The small set constructor will welcome these specially designed "Utility" Components. They save very valuable space and at the same time are thoroughly efficient and fully guaranteed. Your local Wireless Dealer will be pleased to show them to you: ask him to do so.

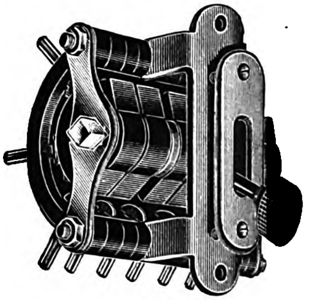
Utility

GUARANTEED

COMPONENTS

Made and guaranteed by

WILKINS & WRIGHT Ltd.,
"UTILITY" WORKS,
Holyhead Road, BIRMINGHAM.

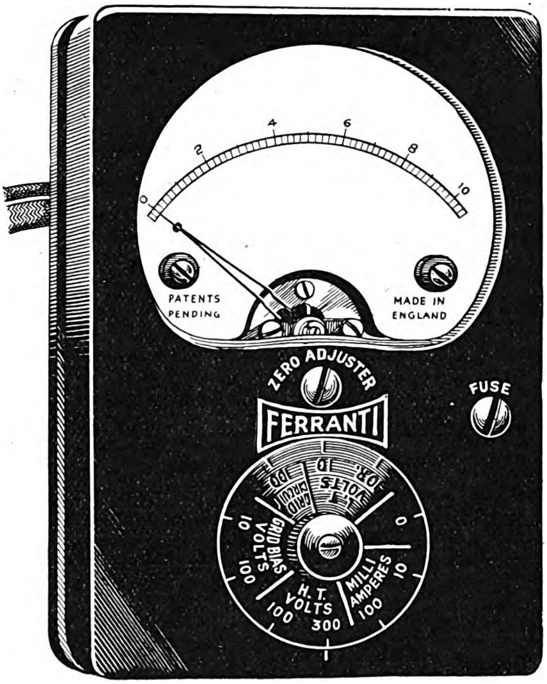


MINIATURE ANTI-CAPACITY SWITCH

A component of entirely new design, and little larger than the illustration. Fixed contacts moulded into Bakelite; movable contacts of double nickel silver spring. Action delightfully resilient and smooth. Arranged for panel or baseboard mounting, and (where ordered) for GANGING.

PRICES

No. W.190/1	1 pole	change-over	4/6
" W.190/2	2 "	change-over	5/-
" W.190/3	3 "	change-over	6/-
" W.190/4	4 "	change-over	7/6
" W.190/5	5 "	change-over	9/6
" W.190/6	6 "	change-over	9/6



THE VALVE TESTER

is a new Ferranti Production of the greatest interest and utility to the serious Radio experimenter.

It eliminates guess-work and enables valves to be accurately tested under actual working conditions whilst the set is in operation.

Each Valve can be tested in turn, easily and with absolute certainty.

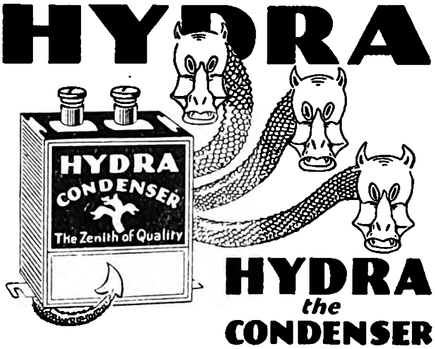
This testing instrument de luxe gives the following readings at the mere turning of the one switch :—Plate Volts, Plate Current, L.T. Volts, Grid Bias Volts, Grid Circuits.

Price: £5 : 15 : 0

FERRANTI LTD. HOLLINWOOD LANCASHIRE

FERRANTI

HYDRA



HYDRA
the
CONDENSER
for all Mains Units

HYDRA was the first commercial condenser to be sold under guarantee of a test at 500 volts. It is still the most popular condenser that manufacturers of Mains Units use exclusively in the smoothing circuit. To amateur constructors of Mains Units Hydra Condensers make all the difference between success and failure—ensuring trouble-free Mains supply for all time.

PRICES:

2 mfd. - 4/- 1 mfd. - 3/-

Tested at 500 volts A.C. Work voltage 240 A.C. at 50 M.A.

Do not accept a silver grey condenser without the Hydra label. Others are imitations and we are not responsible in case of breakdown.

Of all radio dealers. In case of difficulty, write

LOUIS HOLZMAN
34, Kingsway, LONDON, W.C.2

Wireless Valve Transmitters

By W. James

THE DESIGN AND OPERATION OF SMALL POWER APPARATUS

This book deals thoroughly with the design and operation of valve transmitters. Written by a recognised authority who has had a wide experience in the design and construction of valve transmitting sets, it is essentially a book for the practical amateur experimenter.

270 pages: 210 photographs and diagrams.

Price 9/- net. By post 9/6.

From leading booksellers or direct from the Publishers:

ILIFFE & SONS LTD., E.W.1
Dorset House, Tudor Street, LONDON, E.C.4.

JOURNAL OF
SCIENTIFIC INSTRUMENTS

THE NOVEMBER Number contains papers on Ultra-Violet Microscopy, by L. C. Martin, D.Sc., and B. K. Johnson; The Pilot Balloon Slide Rule, by F. J. W. Whipple, M.A., Sc.D., F.Inst.P.; Testing Instruments for Yarns and Fibres, by W. S. Denham, D.Sc., F.I.C., and T. Lonsdale, M.Sc., F.Inst.P.; The Errors Associated with High Resistances in Alternating Current Measurements, by R. Davis, M.Sc.

NEW INSTRUMENTS described include a Tuning Fork Controlled Audio Oscillator, and a New Aquarium Microscope.

A LABORATORY Method of Maintaining Constant Humidity in Closed Chambers is described by R. H. Stoughton, B.Sc., A.R.C.S.

THE subscription rate is 30/- per annum; post free.

THE current number may be obtained from the publishers (price 2/6, post free 2/8), THE CAMBRIDGE UNIVERSITY PRESS, Fetter Lane, London, E.C.4.

JOURNAL OF
SCIENTIFIC INSTRUMENTS

WIRELESS
DIRECTION FINDING
and
DIRECTIONAL RECEPTION
By R. KEEN, B.Eng. (Hons.)

SECOND EDITION: Revised and Enlarged

THIS volume describes the principles of Direction and Position Finding in this country in such a way that the subject may be grasped easily by engineers tackling this field of wireless work for the first time. Constructional details of Direction Finding installations are given and the book includes some information concerning aircraft installation. Numerous photographs and diagrams are included.

Price 21/- net :: By post 21/9

From leading booksellers or direct from the Publishers:

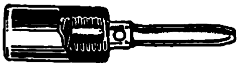
E.W.2 ILIFFE & SONS LIMITED
Dorset House, Tudor Street, London, E.C.4

CLIX

For every conceivable form of contact.

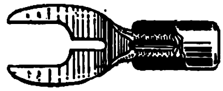
Whatever your Radio interest, whether it be experimental, the "hooking-up" of various circuits, or the construction of finished receivers, you will need some of the Clix products illustrated below. Whatever form of contact you require, they will enable you to obtain it more speedily and with greater certainty of electrical contact.

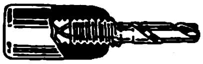
"CLIX" practical aids to perfect contact are the outcome of careful study into the causes of those annoying interferences in reception which are invariably traced to bad contact.



CLIX PARALLEL PLUGS. A boon to experimenters. **2d.**

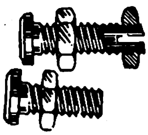
CLIX SPADE TERMINALS. Bury all contact troubles. Nickel-plated or Lead-plated for accumulators **2d.**

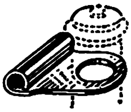




CLIX SPIRAL WANDER PLUGS. Give full surface contact - - - - - - - **2d.**

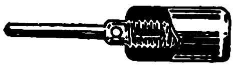
CLIX PARALLEL SOCKETS. Eliminate the use of solder. **1d. & 1½d.**





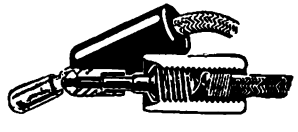
CLIX TERMINAL BRACKETS. Make plug contact simple - **1d.**

CLIX PIN TERMINALS. The pins with many uses. **2d.**



CLIX COIL PINS. An all-purpose fitment - **2d.**

CLIX-LOX WANDER PLUG. The wonder wander plug. **2½d.**



Look for the "CLIX" Showcase on your Dealer's counter.

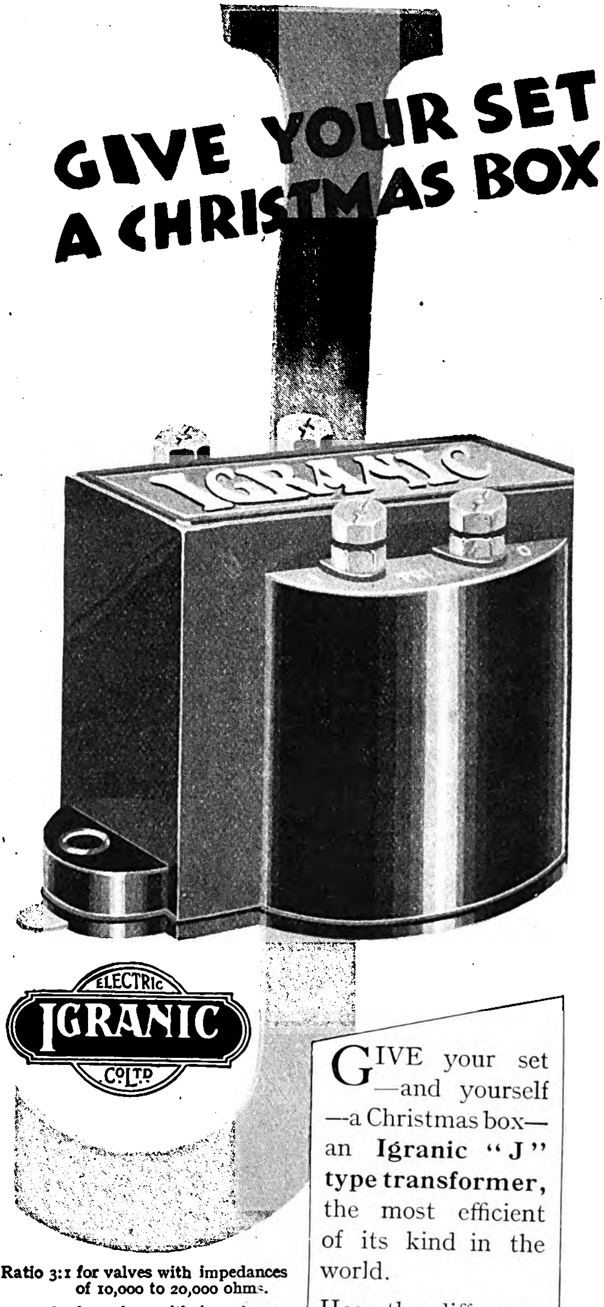
NEW CATALOGUE NOW READY.

It contains full details of all the above and also illustrations, including the following additional "Clix" products:

ACCUMULATOR KNOBS, PANEL TERMINALS, "POWER" PLUGS & SOCKETS, CONNECTORS, AND THE "CLIX" MULTI-PLUG & SOCKET.

Ask your Dealer for a copy, or write to

LECTRO LINX, LTD.,
254, Vauxhall Bridge Rd., Westminster, S.W.1.



GIVE your set—and yourself—a Christmas box—an **Igranic "J" type transformer,** the most efficient of its kind in the world.

Hear the difference it makes!

Ratio 3:1 for valves with impedances of 10,000 to 20,000 ohms.
„ 6:1 for valves with impedances of 5,000 to 10,000 ohms.

Price **17/6**

There is an Igranic transformer for every purpose. Send to-day for illustrated list.

IGRANIC ELECTRIC C° L^{TD}
149, Queen Victoria Street,
LONDON, E.C.4.

J721

When you Experiment—
Make sure you use the best Components

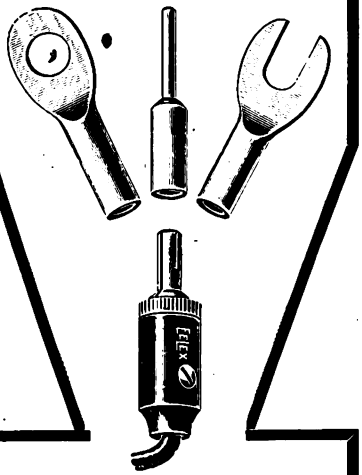
EELEX

TREBLE-DUTY TERMINALS

stand up to their job. You can safely make them the centre of industry in your set. Perhaps you have experienced faulty connection causing bad reception?

THIS IS AN IMPOSSIBILITY WITH EELEX.

For ease of wiring, neatness of appearance and all-round excellence they are unexcelled.



Pin, spade, eye and plug as indicated above, six different colours, 2d. each. Your requirements fully met with Eelex Treble-Duty Terminals and standard plug and socket system.

Send for our free comprehensive booklet Z.D. This interesting booklet gives you full particulars of the above and many other Eelex accessories.

J. J. EASTICK & SONS,
Eelex House, Bunhill Row, E.C.1.
'Phone: Clerkenwell 9282.

PREPAID PARAGRAPH ADVERTISEMENTS.

The Charges for prepaid advertisements are as follows:—

AUCTIONEERS' & OFFICIAL ANNOUNCEMENTS.—*Advertisements under this heading are inserted at a charge of 11s. per single column inch.*

TRADE & MISCELLANEOUS.—*2s. for 12 words and 2d. for each additional word.*

PRIVATE SALE & EXCHANGE.—*Advertisements are inserted in this section at the rate of* One Penny *per word; minimum charge per advertisement* One Shilling. *All advertisements, without exception, must be prepaid to ensure insertion. Single letters or figures are charged as words, and a compound word as two words. The advertiser's name and address are charged for.*

" Box " replies, *care of these offices, are charged 6d. extra to cover postages. The following words must appear at end of advertisements:* " Box—— EXPERIMENTAL WIRELESS *Offices," for which usual rate will be charged. (Advertisers need not include our full address.)* When replying to a " Box No " advt., *address your envelope: Advertiser, Box——,* EXPERIMENTAL WIRELESS & WIRELESS ENGINEER, *Dorset House, Tudor Street, London, E.C.4.*

Remittances should be made by Postal Order or Stamps, and sent to the Advertisement Manager, EXPERIMENTAL WIRELESS & WIRELESS ENGINEER, *Dorset House, Tudor Street, London, E.C.4.*

ORDERS & CHEQUES *should be made payable to* ILIFFE & SONS LTD., *and crossed " and Co." Treasury Notes, being untraceable if lost in transit, should not be sent as remittances.*

FOR DEPOSIT SYSTEM, SEE OCTOBER ISSUE.

PATENTS.

The Proprietors of British Patent No. 227224 are prepared to sell the patent or to licence British Manufacturers to work thereunder. It relates to improvements in thermionic valves.—Address: Boult, Wade & Tennant, 112, Hatton Garden, London, E.C.1. [0165

The Proprietor of British Patent No. 176128 is prepared to sell the patent or to license British Manufacturers to work thereunder. It comprises a wireless signalling system having inductively coupled two loop aerials.—Address: Boult, Wade & Tennant, 112, Hatton Garden, London, E.C.1. [0169

" DICTIONARY OF WIRELESS TECHNICAL TERMS,"

compiled by S. O. Pearson, B.Sc.

Containing concise definitions of all wireless terms; well illustrated and cross-referenced.

Price 2/- net, by post (home and abroad) 2/2 from
ILIFFE AND SONS LTD.,
Dorset House, Tudor St., London, E.C.4,
and leading booksellers.

BUY YOUR RECORDS WITH YOUR WIRELESS

WITH the opening of our new gramophone saloon, another extension to our rapidly growing business, it is now possible for all lovers of music to purchase gramophone records at the same time as their wireless parts and accessories.
We have already been appointed official agents for

COLUMBIA ZONOPHONE HIS MASTER'S VOICE PARLOPHONE ETC.

and other leading makes, and hold large stocks for immediate delivery. Pay a visit to our gramophone saloon, hear and choose your own records in comfort.

XMAS PRESENTS

Solve your Xmas present problem by visiting our showrooms. What could be more acceptable as a present than a portable gramophone, a small table grand, or a few good records? Or if for wireless enthusiasts, a low-priced portable set or some useful adjuncts such as:—

- **Wet High Tension Battery.**
- **G.E.C. Music Magnet Kit.**
- **Cossor Melody Maker Kit.**
- **New Master 3 Star Kit.**
- **Mullard Portable Five Kit.**
- **Soldometa Soldering Outfit.**
- **Voltmeters.**
- **Ampmeters.**
- **Red Spot Loud Speaker Unit.**
- **New Lion Amplion Speakers.**

If you cannot call, write for our new gramophone booklet " Sound Waves from Days," or Wireless booklet " Rays from Days," or our Comprehensive Catalogue, post free 6d. (free to callers).

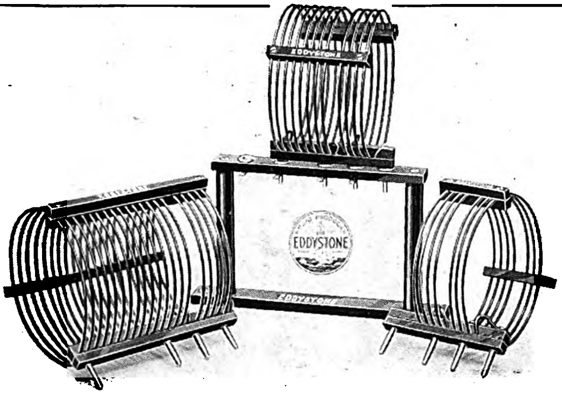
WILL DAY LTD.
(THE BEST IN THE WEST),
18-19, Lisle Street, Leicester Square, W.C.2
Telephone: Regent 0921-0922.
Telegrams: " Titles, Westrand, London."

CONTINUOUS DEMONSTRATIONS FROM 9 A.M.—7 P.M.

EDDYSTONE

SCIENTIFIC SHORT-WAVE APPARATUS.

FIRST AND STILL LEADING.



Duplex Short Wave Coils for Screened-Grid H.F. Circuits.

A set of interchangeable coils designed for use following screened-grid H.F. valves, either in tuned anode or in tuned grid circuits, with Reinartz reaction winding incorporated. Absolutely low loss, yet rigid and strong, with patent four-leaf contact pins. Can also be used as aerial coil with aperiodic coupling. Full instructions and diagrams with each set. B.B.C. and 5X.X. coils obtainable.

Coil D.2.	For 14-39 Metres	with stand.	Price: 19/- per set of three.
Coil D.3.	For 28-63 „		
Coil D.4.	For 43-100 „		

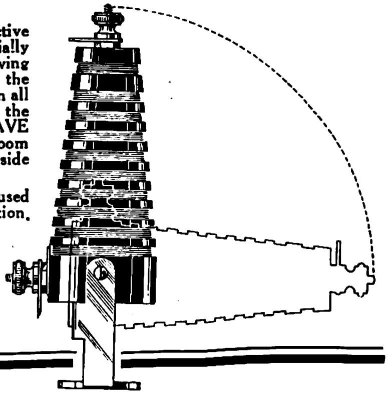
Constructional booklet E.1 for building 3-valve H.F. short-wave set, 6d. post free.

EDDYSTONE SCIENTIFIC H.F. CHOKE.

A redesigned model with an effective range from 14-2,000 metres. Specially suitable for tuned grid circuits following screened-grid H.F. valves where the choke is of vital importance, and in all other positions. Used solely in the "EDDYSTONE" SHORT WAVE receivers. Takes up very little room and has an exceptionally small outside field.

The new mounting enables it to be used in either a vertical or horizontal position.

Price: 6/6 each.



Send for complete list of short wave apparatus.

STRATTON & CO., LTD.,
BROMSGROVE STREET,
BIRMINGHAM.

London Service Depot:
WEBB'S RADIO ELECTRIC STORES,
164, CHARING CROSS ROAD, W.C.2.

A LOW PRICED THERMOJUNCTION.

In response to a demand for Thermojunctions suitable for use with comparatively insensitive instruments, we have produced the range of Vacuum Thermo-Couples described below. These couples have the following unique features.

High Output. 12 to 15 mv. open circuit, or 6 mv. across 3 ohms.

Robust Construction. The joints are welded throughout, which makes it possible for us to guarantee that the couples will be uninjured by overloads of 50%.

Insulated Couple. The couple is insulated from the heater at the junction, thus eliminating parasitic currents.

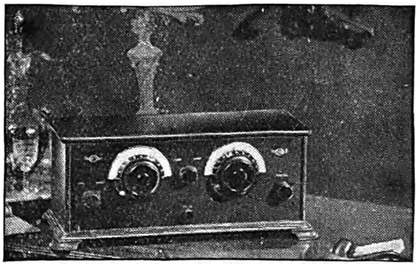
High output couples are made in the following ranges:

Range Current in Milliamps.	Approx. Heater Resistance in Ohms.
25	30
50	8·0
100	2·8
250	1·0
500	0·25
1,000	0·13

For use with more sensitive instruments we make couples giving an output of 6 mv. open circuit for heater currents of 2·5, 5, and 10 m.a.

ELLIOTT BROS. (London), LTD.,
Century Works, Conington Road, Lewisham, S.E.13.
Telephone: Lee Green 1218.

The Sensation of OLYMPIA



THE PENTOVOX THREE.

A bigger brother to the marvellous Pentovox Two, the extra screened grid H.F. Valve extending considerably the range of stations and satisfying, within few limitations the most ambitious "searcher."

The Pentode amplifying valve preserves fine quality of reproduction in ample loud speaker volume.

Wavelength ranges are 250 to 500 metres, and 1,200 to 2,300. There are no coils to change. Log scales are provided to chart the various stations.

List No. 344. Set with three special valves, tested and matched to set. Including Royalty.. .. .. .. **£11 : 0 : 0**

Write for the full literature of Bowyer-Lowe sets and components.

TESTED RADIO **Bowyer-Lowe** APPARATUS

Pentovox 3

Other New Bowyer-Lowe Sets.
The Pentovox Two.
The Vox Populi Screened Three.
The Vox Populi Screened Four.
The Gramo-Radio-phone.
The Senior Cone Reproducer.—Bowyer-Lowe quality applied to loud speaker design and construction.

Bowyer-Lowe Co. Ltd., (Dept. F. Radio Works, LETCHWORTH.

UNIVERSITY OF MINNESOTA
sci,pere v.5

Experimental wireless the wireless eng

3 1951 000 881 022 U

Minnesota Library Access Center
9 ZA R02 D24 S02 TE X